Colorado River Fish Monitoring in Grand Canyon, Arizona—2014 Annual Report

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Colorado River Fish Monitoring in Grand Canyon, Arizona—2014 Annual Report

By David L. Rogowski, Pilar N. Wolters, and Lisa K. Winters

Abstract

The primary goal of the System Wide Electrofishing project is to provide baseline status and trend information on native and nonnative fish in the Colorado River from Lees Ferry to Lake Mead. Annual monitoring has been occurring since 2000. In 2014, one spring (3 -16 April), and one summer sampling trip (24 May to 6 June) were conducted from Lees Ferry to Diamond Creek. One fall sampling trip (20-24 October) was conducted from Diamond Creek to Lake Mead. On the spring and summer trips, 239 and 213 sites were sampled respectively, with 95 sites sampled in the fall trip. In total, 5,734 fish were captured, with native fish comprising 26.6% of the catch. Rainbow trout continue to dominate the catch in Marble Canyon with catch of native species increasing downstream of the Little Colorado River. Catch rates for flannelmouth suckers and rainbow trout remained at relatively high levels, 12.2 fish/hour and 43.0 fish/hour, respectively. For the spring and summer trips nonnative species accounted for 83.6% of the total catch, while for the fall trip nonnative species accounted for 7.1% of the total catch.

Introduction

Long-term fish monitoring in the Colorado River below Glen Canyon Dam is an essential component of the Glen Canyon Dam Adaptive Management Program (GCDAMP), a federally authorized initiative to protect and mitigate adverse impacts to resources downstream from the dam. The U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) is responsible for long-term fish monitoring for the Program, which is implemented in cooperation with the Arizona Game and Fish Department (AGFD), U.S. Fish and Wildlife Service, and others. Electrofishing and tagging protocols have been developed and implemented for standardized annual monitoring of Colorado River fishes since 2000. Long-term monitoring establishes a "baseline," or antecedent context, through which response of biota to changing management policies or experiments can be interpreted and evaluated (Walters and Holling 1990, Thomas 1996, Walters 1997). For example, since 1996, a series of experimental high flows have been released from Glen Canyon Dam as part of a strategy intended to restore sandbars in Grand Canyon, and several stable-flow tests have been conducted to presumably benefit the humpback chub (*Gila cypha*), a species federally listed as endangered. Between 2003 and 2006, an experimental program that used electrofishing removed approximately 20,000 nonnative rainbow trout (*Oncorhynchus mykiss*) near the mouth of the Little Colorado River. During the same period, water temperatures downstream from Glen Canyon Dam increased as drought caused the level of Lake Powell to drop and warmer surface waters were released downstream. Recent management actions include humpback chub translocations to Shinumo Creek in Grand Canyon and installing a fish weir in Bright Angel Creek to remove brown trout (*Salmo trutta*). Long-term fish monitoring can help managers evaluate the effectiveness of these management actions and policies.

The river between Glen Canyon Dam and Lees Ferry is managed as a blue ribbon rainbow trout sport fishery, but GCDAMP goals for nonnative fish below Lees Ferry relate to their impact on native species, particularly humpback chub. Many researchers have suggested that salmonids limit recruitment of native fishes in Grand Canyon through predation (Minckley 1991, Valdez et al. 2001, Marsh and Douglas 1997, Yard et al. 2011). Two panels of external experts evaluated protocols used by GCMRC and its cooperators to monitor fish, and both reviews recommended long-term monitoring of nonnative fish species that pose risks of predation to Colorado River native fishes in Grand Canyon (Anders et al. 2001, Bradford et al. 2009).

Protocols for standardized annual monitoring of native and nonnative fish (rainbow trout, brown trout, and common carp (*Cyprinus carpio*) in the Colorado River were developed and implemented in 2000 and slightly modified subsequently (Speas et al. 2003).[1] We have conducted two fish monitoring trips each year between 2000-2014 using electrofishing, generally between March and May, in the mainstem Colorado River between Lees Ferry and Lake Mead (Fig. 1). However, in 2011 and 2012 the total sampling days were reduced from 40 to 25 due to the cost and logistical problems with long river trips. A fall sampling trip from Diamond Creek down to Lake Mead has been conducted annually since 2012 and sporadically prior to that sometimes in the fall and other times during the spring as part of the spring downstream trip. However, due to a variety of logistical (economic and personnel costs of being on the river for 3-4 weeks at a time) and biological reasons, it was moved to a separate fall trip only, beginning in 2012. It is believed fall was selected as it was after the monsoon season (improved water clarity), water temperatures are highest at this time, and it might be ideal for surveying for warm water non-native fishes that might be moving up from Lake Mead (e.g. striped bass *Morone saxatilis*). In 2015 the reach from Diamond Creek to Pearce Ferry (river mile 280) will be included in the spring/summer sampling trip in addition to a separate fall trip.

Objectives

The goal of the System Wide Electrofishing Project is to provide baseline status and trend information of fishes in the Colorado River. The specific objective for monitoring in 2014 is as follows:

- Describe trends in native and nonnative fishes catch-per-unit-effort (CPUE; fish/hour) and distribution from 2001 – 2014.

[1] Although the U.S. Geological Survey does not typically cite unpublished reports, this report makes reference to several unpublished reports produced by the Arizona Game and Fish Department to provide the reader background information and ensure a complete assessment of fish population trends.

Study Area

All locations in this study are referred to in river miles (RM) starting at Lees Ferry (Coconino County, north-central Arizona; RM 0), approximately one mile upstream of the confluence of the Paria River.[2] The Colorado River from Glen Canyon Dam downstream to Lees Ferry (approx. 16 mi) is not included in this study area. Sampling described in this report was conducted between RM 0 and RM 280 of the Colorado River in Grand Canyon (Fig. 1). In general, the river ranges in character from numerous large eddy complexes in depositional areas to narrow, deeply incised sections in reaches composed of resistant rock types. Water quality is strongly influenced by hypolimnetic water discharged from Glen Canyon Dam near Page, Arizona. Water discharged is typically clear (<5 nephelometric turbidity units; Vernieu 2009) and cold (8–11°C; Stanford and Ward 1991, Voichick and Wright 2007) and has intermediate conductivity (700–900 µS/cm; Vernieu 2009).

Methods

Three electrofishing sampling trips were conducted for this project in spring, summer and fall of 2014. The spring and summer sampling trips encompassed the area within the Colorado River between Lees Ferry and river mile 226 (Diamond Creek). The fall trip covered the river from Diamond Creek to Pearce Ferry, on Lake Mead (RM 280).

To determine sampling sites for each trip a stratified random sampling approach was used. The Colorado River (from Glen Canyon Dam to Lake Mead) has been divided into equal 250 m sites (left and right sides of the river); these constitute our available sample sites. We then divided the river into 11 sections (Table 1), and each section into subsections (n=58) of approximately eight kilometers in length (~5 mi), which were defined in part by location of navigational hazards, such as rapids and available campsites. Samples were allocated to each section based on the percent distance (RM) of each section. Subsections within each section were then randomly selected as were samples within a subsection selected (right or left side of the river). Subsections in the reach between Lees Ferry and Diamond Creek contained on average 43 potential sample sites of 250 m in length (min=11, max = 88). In some instances due to rapids, subsections were as short as two kilometers leaving only eight sample sites per side of river in the subsection; in these instances we sampled all possibly sites within a subsection.

For fall sampling from Diamond Creek to Lake Mead, the Colorado River was divided into 11 sections of five miles each, and pooled within five regions. The last region contained three sections and the others two. For 2014, four regions (for the four nights of sampling) were randomly selected and one section from each region was randomly selected. Twenty four sample sites were then randomly selected within each selected section. Sample sites on the river were identified via the use of a labelled orthophotographic map created by GCMRC in conjunction with a handheld GPS unit with site coordinates pre-loaded.

[2] The use of river mile has a historical precedent and provides a reproducible method for describing locations along the Colorado River below Glen Canyon Dam. Lees Ferry is the starting point, river mile 0, with mileage measured for both upstream (–) and downstream.

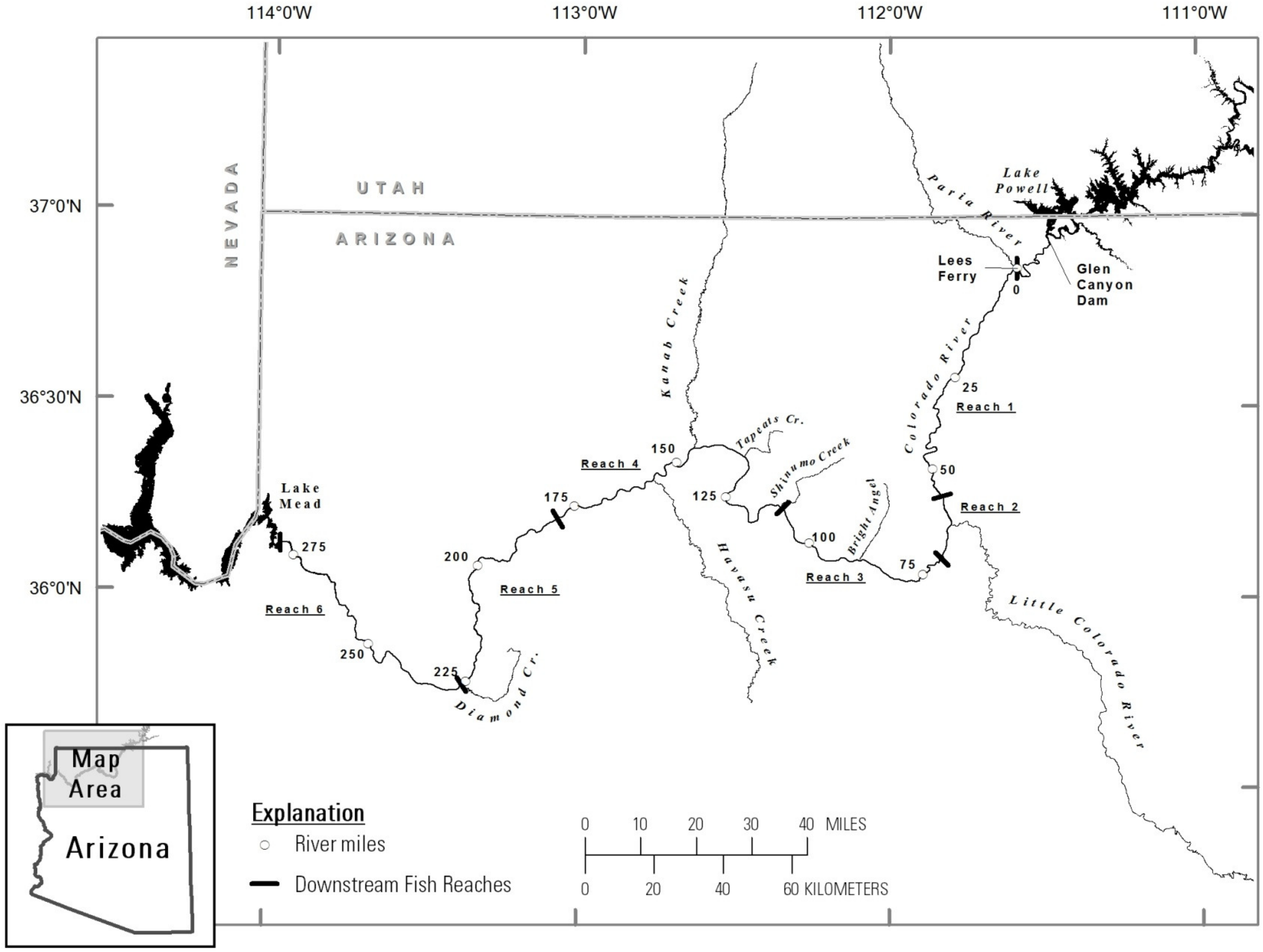

Figure 1. **Map of study area identifying Glen Canyon Dam, Lees Ferry, Lake Mead, and river reaches. River miles starting at Lees Ferry are listed in 25-mile segments. The six reaches analyzed are divided with black bars; reach 1 RM 0-56, reach 2 RM 56.1-69, reach 3 RM 69.1-109, reach 4 RM 109.1-179, reach 5 RM 179.1-225 and reach 6 RM >225.**

Table 1. Allocation of samples for 2014 in the Colorado River between Lees Ferry (RM 0) to Pearce Ferry (RM 280).

Pooled sections (Reach)	Section	Start RM	End RM	Distance (mi)	% of area	# samples	% samples	% of section sampled
1	1	0	29.99	30	11.1	44	8.61	11.4
	2	30	55.99	26	9.6	61	11.9	18.2
2	3	56	68.99	13	4.8	39	7.63	23.3
	4	69	79.99	11	4.1	14	2.73	9.9
3	5	80	109.99	30	11.1	68	13.3	17.6
	6	110	129.99	20	7.4	24	4.70	9.3
4	7	130	159.99	30	11.1	61	11.9	15.8
	8	160	179.99	20	7.4	35	6.85	13.6
5	9	180	199.99	20	7.4	21	4.11	8.1
	10	200	219.99	20	7.4	69	13.5	26.7
6	11	220	270	50	18.5	111	21.7	17.2

We sampled at night (commencing with the appearance of two stars) with two 16-ft Achilles inflatable sport boats outfitted for electrofishing with a Coffelt CPS unit powered by a 5000w Honda® generator; each boat included two biologists and one boatman. The CPS units applied between 300 and 460 volts and 10 to 15 amps to spherical steel electrodes. Each sample consisted of a single electrofishing pass of approximately 600 seconds, along a 250m shoreline transect. Boats and boatmen alternated the side of the river they were sampling each night. Netters were assigned to different boats each night.

We recorded total length (TL, in mm) and fork length (FL, in mm) for native species, and TL only for nonnative species below Diamond Creek. Nonnative fish longer than 150 mm were weighed, as long as conditions allowed accurate measurement with the scale. Common carp greater than 99 mm TL received a Passive Integrated Transponder (PIT) tag and a dorsal spine clip. Brown trout, flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus*) greater than 149 mm TL and humpback chub greater than 99 mm TL were implanted with PIT tags, according to standard protocols for handling fish in Grand Canyon (Persons et al. 2014). Brown trout received an adipose fin clip as a secondary mark. All PIT tag numbers were recorded on data sheets and saved in PIT scanners. Scanner files were downloaded and archived to confirm the accuracy of data sheets and databases. Data were entered into a Microsoft Access® database where quality assurance and quality control using standard software routines were employed. Data were then incorporated into the GCMRC fish database. To allow comparisons to historical data, fork lengths for rainbow trout, brown trout, and common carp were converted to total lengths using correction factors specific to each species.

The formulas used are as follows:

Rainbow trout: $TL = 1.956+1.064\ (FL)$

Brown trout: $TL = 8.211+1.024\ (FL)$

Common carp: $TL = 6.266+1.100\ (FL)$

The 11 sections used in the study design were later grouped into six larger reaches in order to obtain adequate sample sizes for trend analyses. Data were reported as mean CPUE per fish species per reach (plus 95% confidence intervals, CI), with CPUE serving as an index of relative abundance (fish/hour). Length-frequency histograms were created for each species at 10-mm size increments. Rainbow trout and brown trout mean CPUE were also analyzed for areas upstream (RM 41.5-61.5) and downstream from (RM 61.5-81.5) the Little Colorado River confluence.

Turbidity

Electrofishing data collected in turbid water may yield confounding results because of different capture probabilities among turbid and clear water samples (Speas et al. 2004); therefore, past data collected during turbid water conditions were not included in historical CPUE analyses. In the past, personnel classified water turbidity as being either high or low. Turbidity measurements were often not taken nor reported for past sampling trips. Beginning in 2013, turbidity measurements in Nephelometric Turbidity Units (NTU) were collected each evening before electrofishing using a Hach 2100P turbidity meter.

A previous trip report mentioned turbidity readings greater than 700 NTU resulted in reduced catch (Rogers 2005). For 2009 and 2010 during one trip each, data was not analyzed below the LCR as a result of high turbidity. However, we have no record of what those turbidity values were that justified exclusion of data from 2009 and 2010. Data sheets only report turbidity as "high". It appears that the quality of data collected in turbid water was assessed solely on the recollection of the data analyzer; meaning that the decision to exclude data due to high turbidity was made in the office during data analysis. USGS gage data revealed that the average turbidity [95% confidence intervals] for the nights and times fished in 2009 was 226 [199, 253] and 2010 was 213 [202, 224], using the gage located at Phantom Ranch (USGS 09402500) for nights fished between the LCR and Bright Angel Creek, and the gage at Diamond Creek (USGS 0904200) for nights fished below Bright Angel Creek. The USGS used Formazin nephelometric units (FNU) which are essentially equivalent to NTU if calibrated using the same formazin standard (Sadar 2004; but see: Davies-Colley and Smith 2001 for a critique).

Results

In 2014, we conducted three electrofishing trips in the mainstem Colorado River between Lees Ferry and Lake Mead (RM 0 and RM 280). The river section between Lees Ferry and Diamond Creek was sampled in the spring and early summer, while the section between Diamond Creek and Pearce Ferry was sampled in the fall (Table 2). Conditions of the river differed for each trip (Table 2, Figure 2, Appendix A).

Table 2. AGFD summary sample data and river conditions [mean (range)] during Colorado River sampling in 2014. Discharge, turbidity, and temperature from the first two trips are from USGS gage 09402500 near Phantom Ranch, and for the fall trip from USGS gage 09404200 above Diamond Creek.

Trip ID Date	Sites	Discharge (CFS)	AGFD Turbidity (NTU)	Turbidity (FNU)	Temperature (°C)
GC20140403 3-16 May	239	8721 (6220-11000)	6.71 (3.9-11.3)	3.1 (1.7-8.7)	12.4 (11.05-13.5)
GC20140524 24 May – 6 June	213	8963 (5920-13700)	7.78 (3.35-20.7)	5.8 (1.8-64)	13.9 (12.5-15.3)
GC20141020 20 - 24 Oct.	95	10590 (8610-12800)	507 (434-569)	152 (70-275)	16.5 (16.0-17.1)

CFS: cubic feet per second
FNU: Formazin nephelometric units
NTU: Nephelometric turbidity unites

For a variety of reasons, during the summer sampling trip fewer samples were collected than planned. A new contract for boatmen was in place for our second downstream trip (summer) thus we had boatmen that had never driven an electrofishing boat or had little to minimal experience in electrofishing. As a result, some of our sampling transects ended up being unusable due to recording or other errors. Fish captured from sites that were not used for overall CPUE analyses were still entered into the database, but as supplemental information. In addition, a seam on one of the inflatable electrofishing boats failed, rendering the boat unusable for sampling on the last day of the second trip.

We completed 547 standard transects (samples). For the spring and early summer trips electrofishing transects averaged 612 seconds per site. The fish community included 14 different species captured (Table 3). Mean CPUEs for the six most common fish captured by river section are presented in Table 3 and Figure 3. During standardized electrofishing a total of 5,734 fish were captured, including two flannelmouth X razorback sucker hybrids. A total of 939 fish were marked this year with PIT tags. A total of 189 fish encountered during 2014 were recaptured fish tagged from a prior sampling event. Recapture history were available for 42 PIT tagged fish (Appendix B), however, the other PIT tagged fish (majority rainbow trout) did not have initial capture information available in the GCMRC fish dataset at the time of this report.

For the fall trip we had the unique ability to compare an experienced boatmen against a boatman with little to no experience electrofishing. As sample sites were randomly selected within sections and regions (five mi segments), and netters were rotated among boats we think that this was a valid comparison. We conducted an analysis of variance on boatmen CPUE (log10(x)) in relation to hydraulics (eddy, run, riffle, etc...) and shoreline habitat. We dropped one of the samples from the analysis as it was an outlier (142 juvenile fish were captured). There was a significant effect of boatmen on CPUE (Table 4) with the experienced boatman averaging 9.75 [6.59, 12.91] fish/hour and the inexperienced boatman averaging 3.74 [2.16, 5.33] fish/hour.

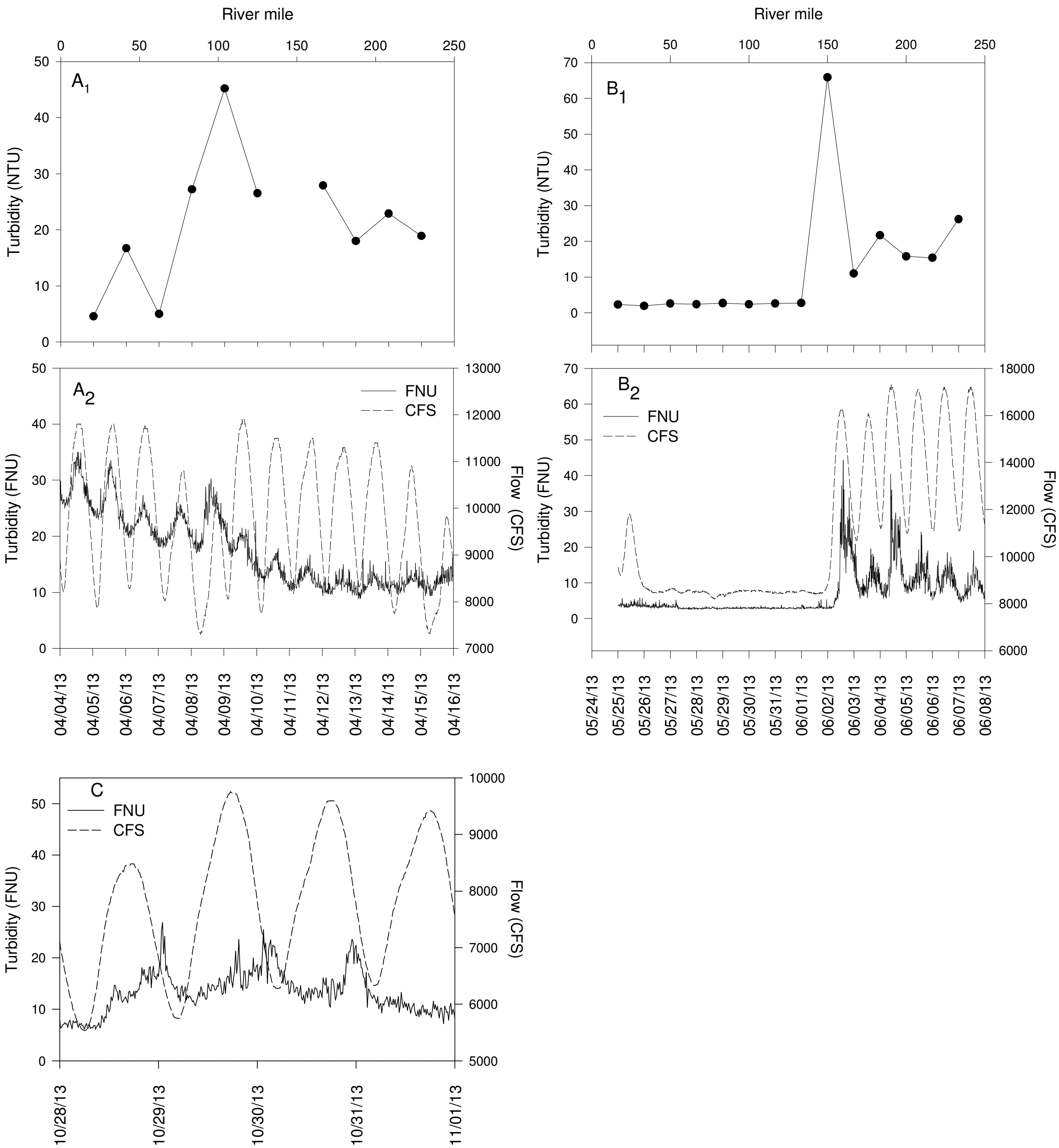

Figure 2. Colorado River conditions during AGFD sampling trips. Nightly turbidity readings (Nephelometric Turbidity Units (NTU)) for trip GC20130404 (A1) and trip GC20130525 (B1). Daily turbidity (Formazin Nephelometric Units) and flow (cubic feet/second) as measured by the USGS gage at Phantom Ranch ~RM 87; GC20130404, A2, GC20130525, B2, and GC20131028, C. 1 NTU ~ 1 FNU

Table 3. Species composition and mean catch per unit effort (CPUE: fish/hour) from system wide boat electrofishing Colorado River from Lees Ferry to Lake Mead for 2014 (only data used in calculating CPUE presented).

Species	LF-DC	DC-LM	Sum	Percent of total catch	Overall CPUE [95 % CI]
Native					
Bluehead sucker (BHS)	43	27	70	1.22	0.838 [0.570, 1.10]
Flannelmouth sucker (FMS)	689	391	1080	18.84	12.2 [8.98, 15.4]
Humpback chub (HBC)	13	3	16	0.279	
Speckled dace (SPD)	63	242	305	5.31	3.30 [2.29, 4.31]
Unidentified sucker (SUC)	9	41	50	0.871	
Flannelmouth X Razorback (FRH)	0	2	2	0.0349	
Total	817	706	1523	26.6	
Nonnative					
Black bullhead (BBH)	1	0	1	0.0174	
Brown trout (BNT)	129	0	129	2.25	1.46 [3.21, 5.60]
Channel catfish (CCF)	0	1	1	0.0174	
Common carp (CRP)	158	11	169	2.95	1.94 [1.47, 2.41]
Fathead minnow (FHM)	12	19	31	0.5406	
Gizzard shad (GZD)	2	3	5	0.0872	
Mosquitofish (MOS)	0	5	5	0.0872	
Rainbow trout (RBT)	3855	5	3860	67.32	43.0 [36.1, 49.8]
Red shiner (RSH)	0	5	5	0.0872	
Unidentified fish (UIF)	4	4	8	0.0698	
Yellow bullhead (YBH)	0	1	1	0.0174	
Grand total	4978	760	5738	100.0	

LF = Lees Ferry; DC = Diamond Creek; LM = Lake Mead

In this report we present results for native fish first followed by the nonnative fish. As our sampling approach and data collected is primarily designed for detecting general trends over multiple years (3-5), we present results from previous years as a comparison, and test for statistical trends over the past five years using regression analyses.

The Little Colorado River is important for the native fish of the Colorado River Basin (Valdez and Ryel 1995). It is the primary spawning and rearing habitat for the native suckers, particularly the humpback chub (Gorman and Stone 1999; Coggins et al. 2006, Yackulic et al. 2014). Nonnative fishes threaten native fishes in the Colorado River (Valdez and Ryel 1995). As such, the Glen Canyon Dam Adaptive Management Program began a removal program for nonnative fishes and removed more than 19,000 rainbow trout between 2003 and 2006 in the mainstem Colorado River around the LCR (Coggins 2008; Coggins et al. 2011, Yard et al. 2011). Thus there is concern about the status of trout around the LCR inflow to the Colorado River and we present CPUE data for the 20 mi reaches immediately above and below the confluence.

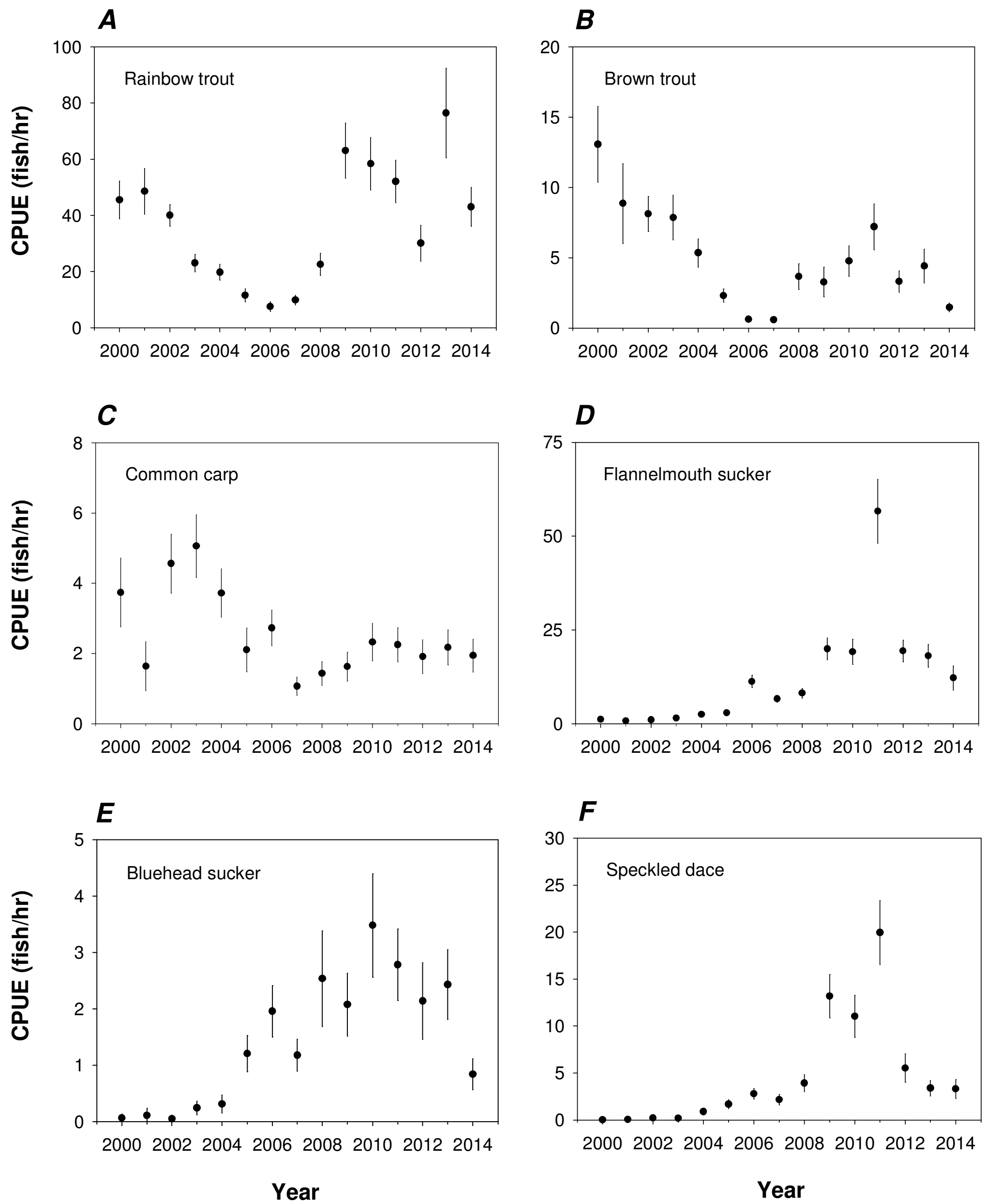

Figure 3. River-wide mean catch per unit effort results by year from Lees Ferry (RM 0) to Lake Mead (~ RM 280) for the 6 key species. Error bars represent 95% confidence intervals.

Table 4. **Summary results from ANOVA of boatmen CPUE from the fall trip, from Diamond Creek to Pearce Ferry.**

Source	DF	Sum of Squares	Mean Square	F Ratio	P
Model	17	8.09	0.735	4.89	<0.001
Error	83	12.5	0.150		
Corrected Total	94	20.6			
Effect Tests					
Hydraulic	3	0.765		1.70	0.174
Boatmen	1	1.42		9.49	0.0028
Habitat	7	4.80		4.56	0.0002

DF: degrees of freedom

Table 5. Summary of regression analyses performed on the past 5 years of mean catch per unit results for the most common native and nonnative species captured during river-wide boat electrofishing of the Colorado River, Lees Ferry to Lake Mead.

	Species	F-value	df	P-value
Native				
	Bluehead sucker (BHS)	15.3	4	0.0296
	Flannelmouth sucker (FMS)	0.824	4	0.431
	Speckled dace (SPD)	3.17	4	0.173
Nonnative				
	Brown trout (BNT)	3.00	4	0.182
	Common carp (CRP)	3.24	4	0.169
	Rainbow trout (RBT)	0.00100	4	0.926

df: degree of freedom

Native Fish

Flannelmouth Sucker

River-wide mean CPUE for flannelmouth sucker in 2014 was 12.2 fish/hour (Figure 3). There was no significant trend in river-wide mean CPUE for flannelmouth sucker over the past five years (Table 5), despite an exceptionally high catch in 2011. Flannelmouth sucker mean CPUE significantly increased downstream by reach (regression: $F_{1,5}$ = 095.1, P = 0.0000619; Figure 4). Mean CPUE was lowest in Reach 1, 0.78 fish/hour [0.324, 1.23], and highest in Reach 6, 25.9 fish/hour [9.02, 42.8] this is similar to previous years (Figure 5). According to the length frequency distribution, there appears to be two size cohorts present in 2014 (Figure 6).

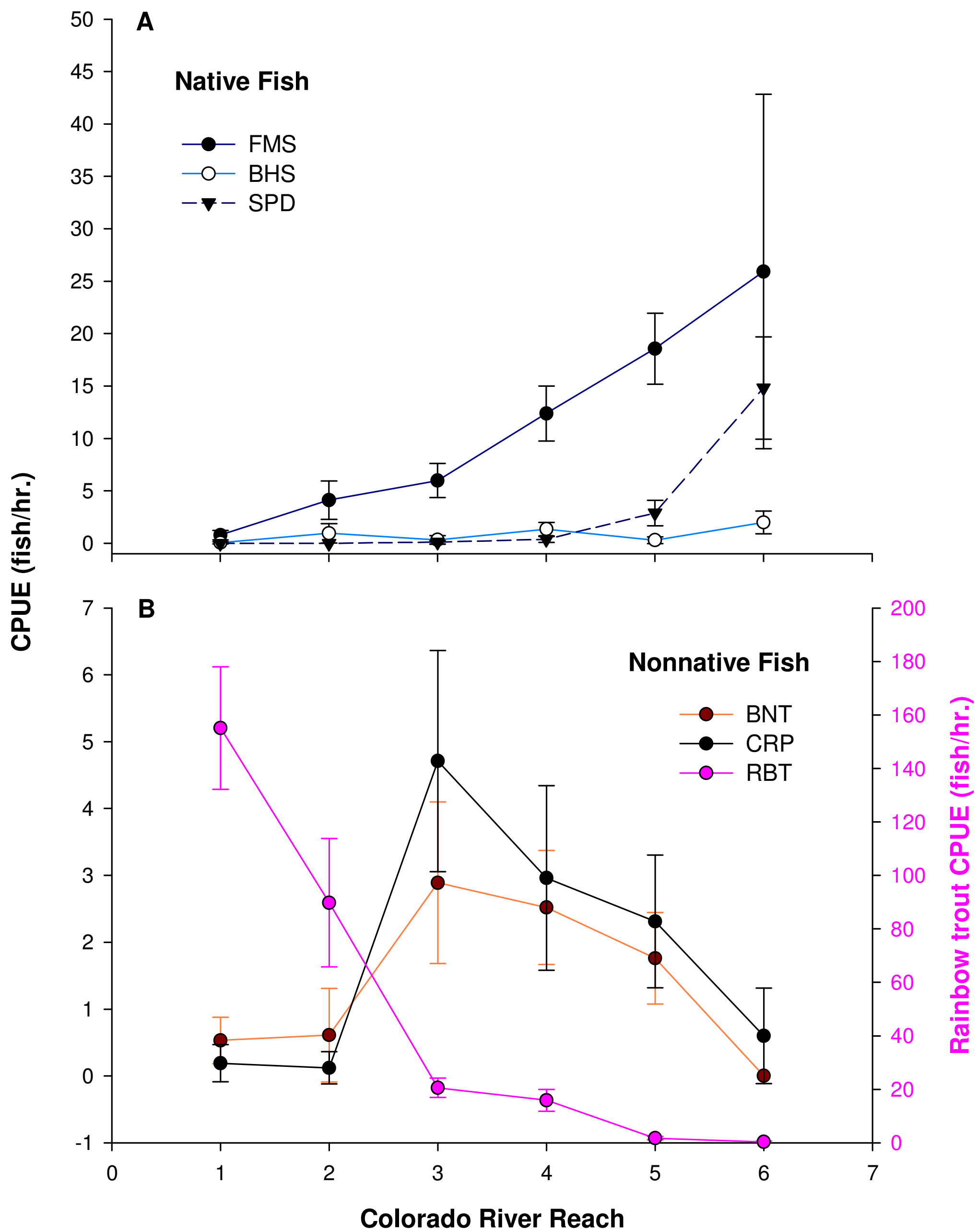

Figure 4. Mean CPUE of species by Colorado River reach of native (A) and nonnative fish (B) for 2014. Note that rainbow trout (RBT) CPUE is on the right vertical axis in pink in a different scale.

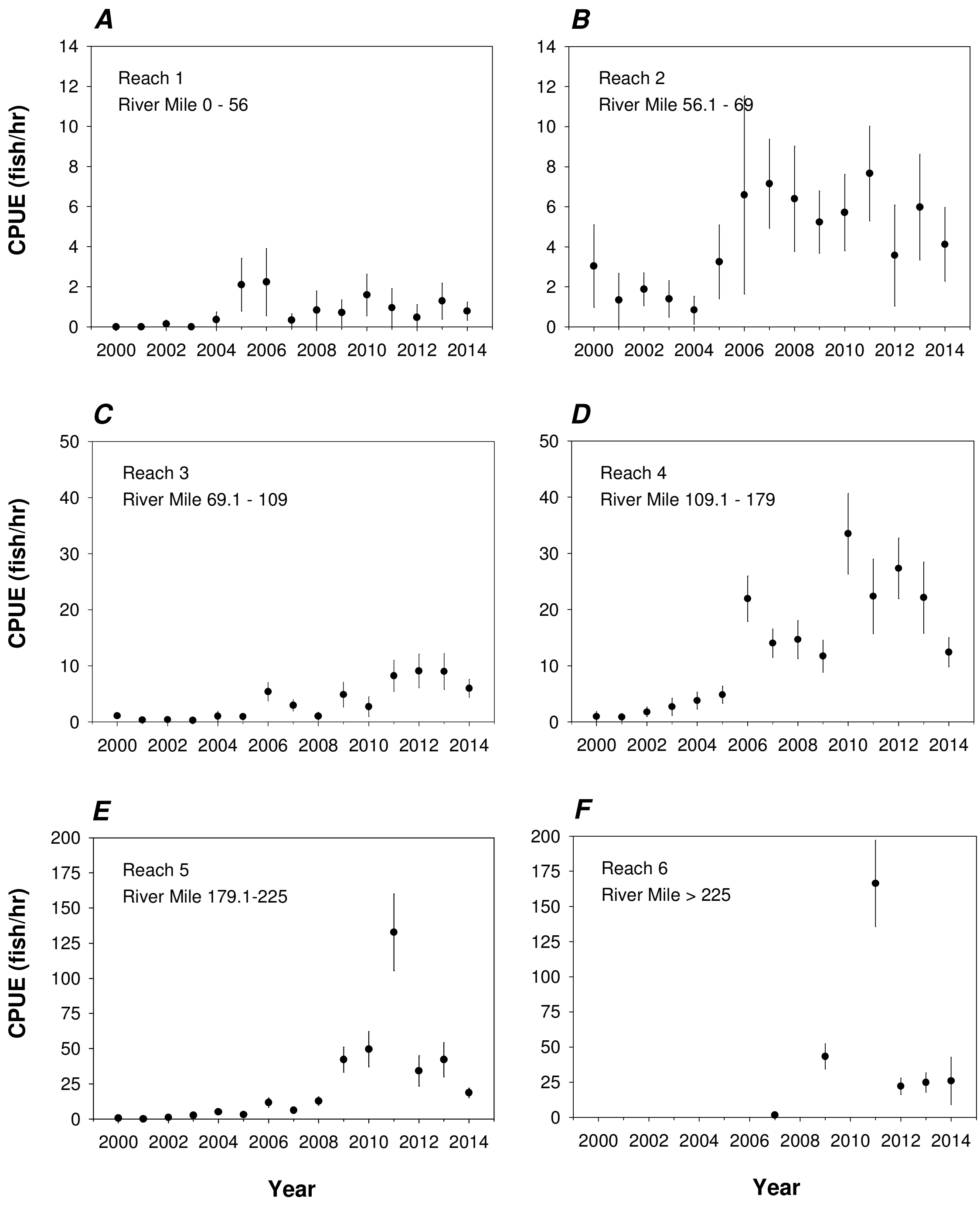

Figure 5. Mean CPUE (fish/hour) of flannelmouth sucker captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014. Error bars represent 95% confidence intervals. Reach 6 was sampled in 2004-2006 and 2010, but data was not included because of high turbidity. Note: different Y axis scales between graphs; the number of sample sites differ from year to year.

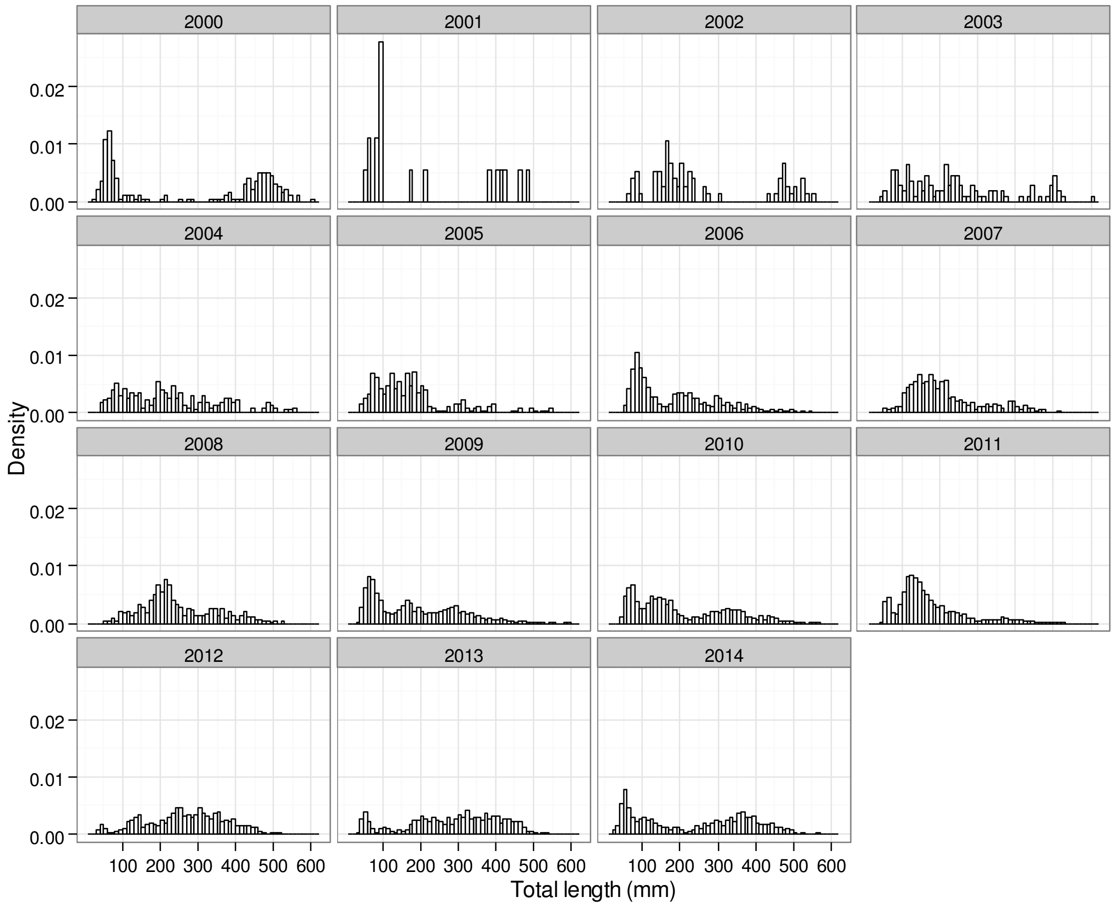

Figure 6. Length-frequency distribution of flannelmouth sucker captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014, all reaches. Note: the number of sample sites differs from year to year.

Bluehead Sucker

River-wide mean CPUE for bluehead sucker was 0.84 fish/hour (Figure 3). There was a significant decrease in the mean CPUE over the past five years (Table 5).There was no significant trend in mean bluehead sucker CPUEs by reach (regression: $F_{1, 5} = 2.59$, $P = 0.182$; Figure 4). Mean CPUE was lowest in Reach 1, 0.05 fish/hour, and highest in Reach 6, 2.00 fish/hour [0.911, 3.09] this is similar to previous years (Figure 7). The length frequency distribution (Figure 8) show no distinct cohorts, possibly due to low sample size (n = 75).

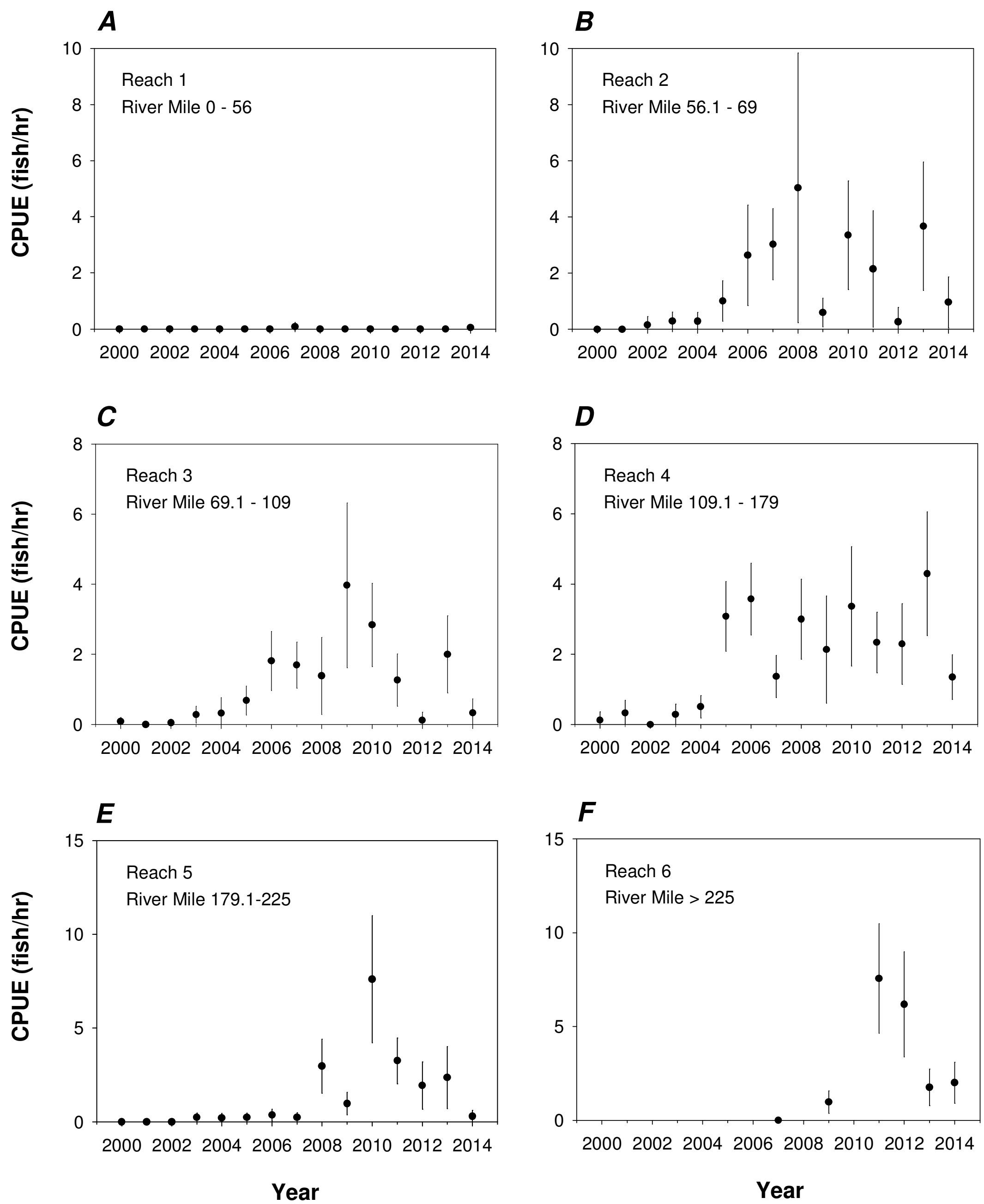

Figure 7. Mean CPUE (fish/hour) of bluehead sucker captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014. Error bars represent 95% confidence intervals. Reach 6 was sampled in 2004-2006 and 2010, but data was not included because of high turbidity. Note: different Y axis scales between graphs; the number of sample sites differs from year to year.

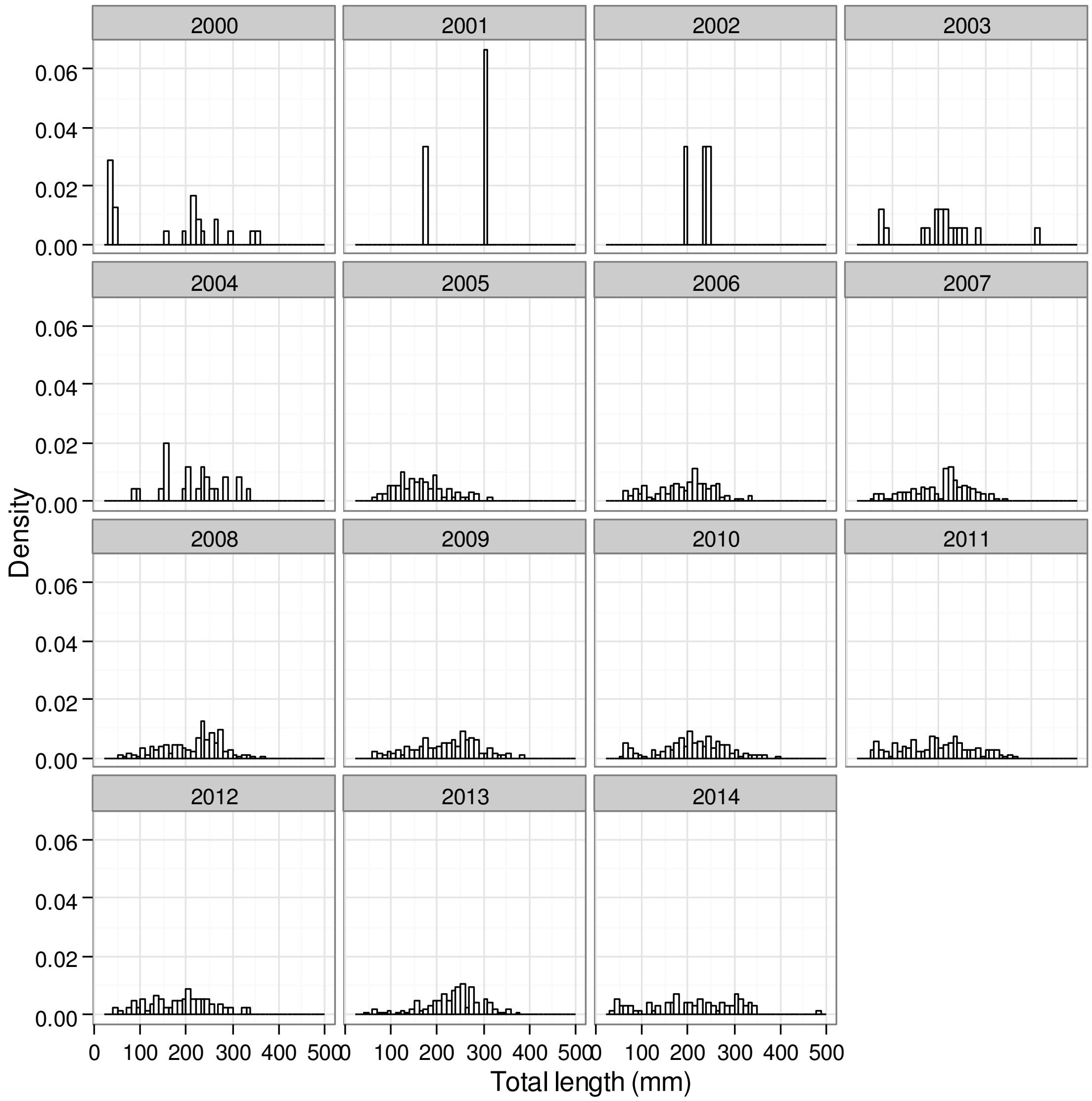

Figure 8. Length-frequency distribution of bluehead sucker captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014, all reaches. Note: the number of sample sites differs from year to year.

Speckled Dace

River-wide mean CPUE for speckled dace was 3.3 fish/hour in 2014 (Figure 3). There wasn't a significant trend in the mean CPUE over the past five years (Table 5). Speckled dace CPUE appeared to increase downstream by reach but was not significant (regression: $F_{1,5}$=5.29, P = 0.0829; Figure 4). Speckled dace mean CPUE increased downstream, with the lowest values in Reach 1 and 2, with no fish caught, and highest in Reach 6, 14.82 fish/hour [9.94, 19.7] this is similar to previous years (Figure 9). The length frequency distribution does not appear to display any discernible size cohorts present in 2014 (Figure 10).

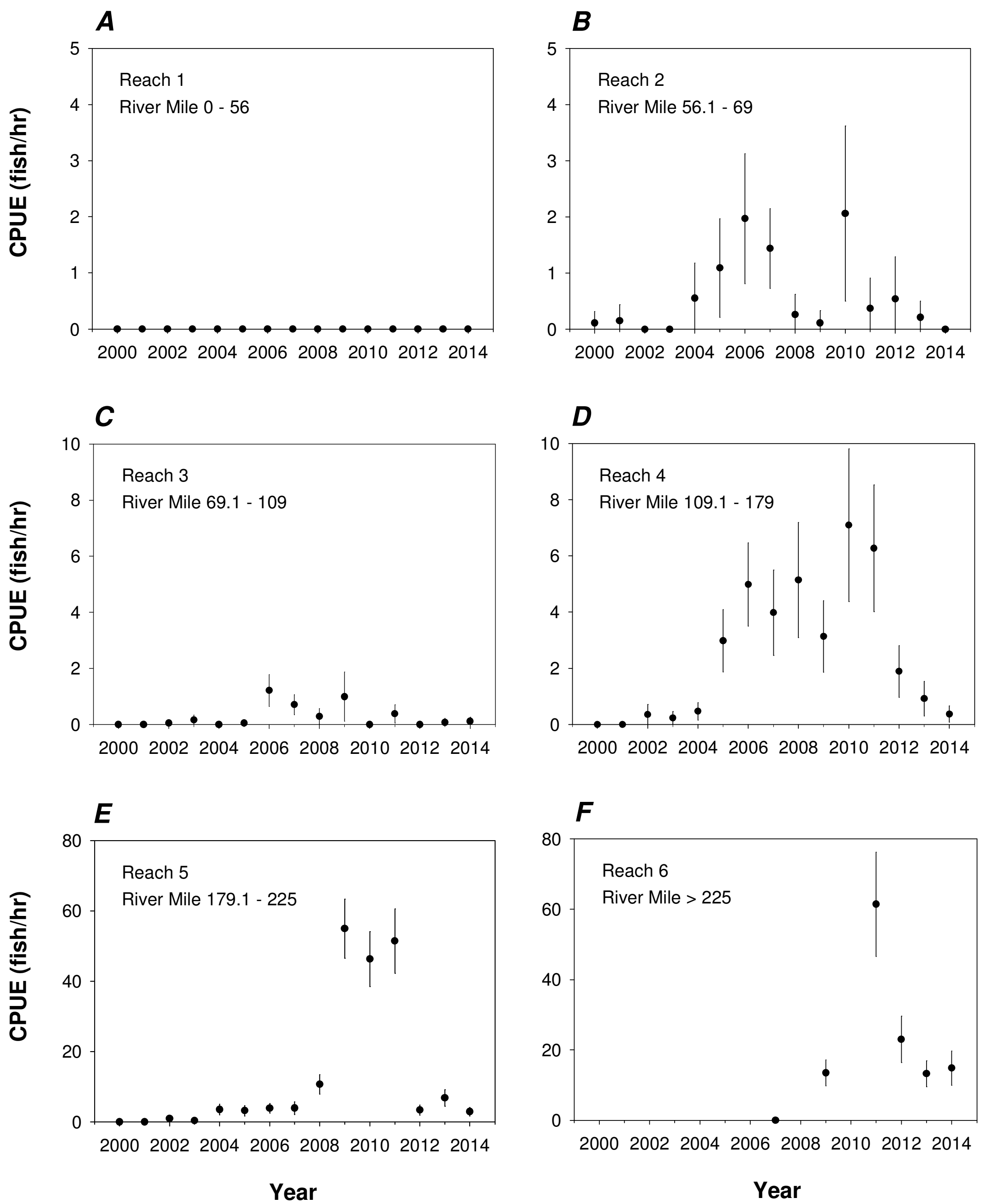

Figure 9. Mean CPUE (fish/hour) of speckled dace captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014. Error bars represent 95% confidence intervals. Reach 6 was sampled in 2004-2006 and 2010, but data was not included because of high turbidity. Note: different Y axis scales between graphs; the number of sample sites differs from year to year.

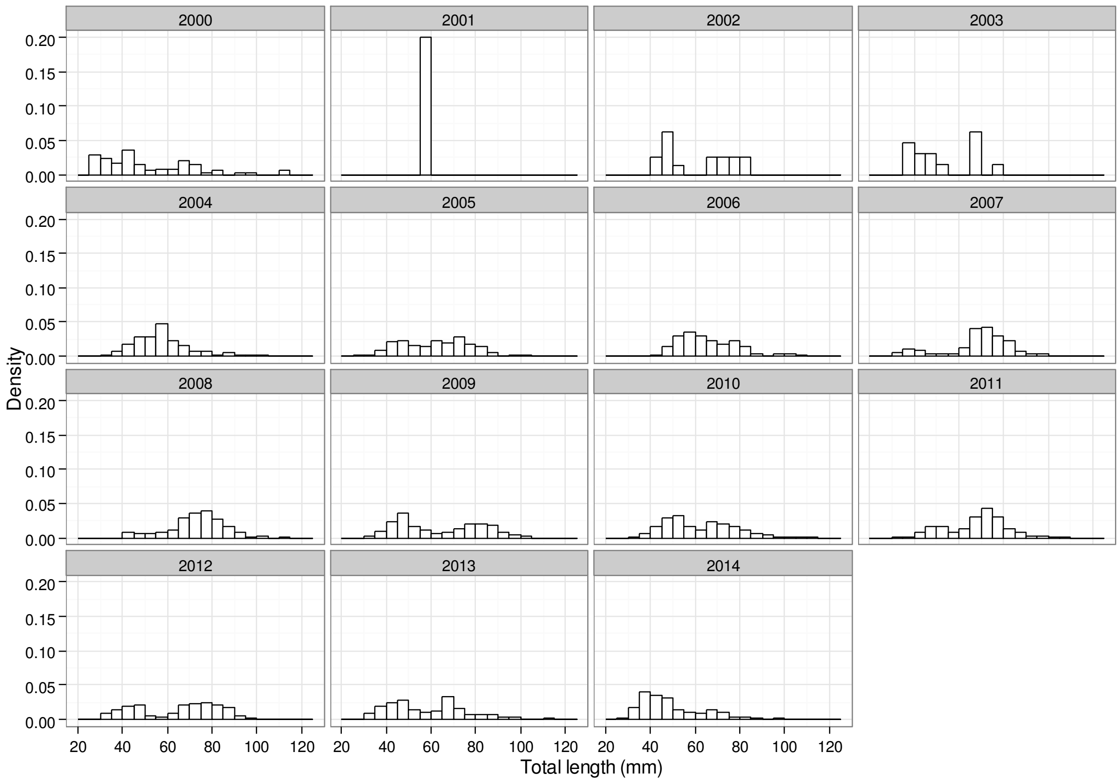

Figure 10. Length-frequency distribution of speckled dace captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014, all reaches. Note: the number of sample sites differs from year to year.

Other Native Fish

We captured two flannelmouth sucker X razorback sucker hybrids measuring 481 mm and 137 mm TL. Their capture locations were RM 240 (Separation Canyon) and RM 261 (~2 miles below Quartermaster Canyon). Only 16 humpback chub were captured, too few to complete CPUE and length-frequency analyses (Table 3). Analysis of humpback chub count data shows a substantial decline from almost 1,400 chub captured during electrofishing surveys in 1993, to an average of 13 chub captured each year in the past decade (Figure 11).

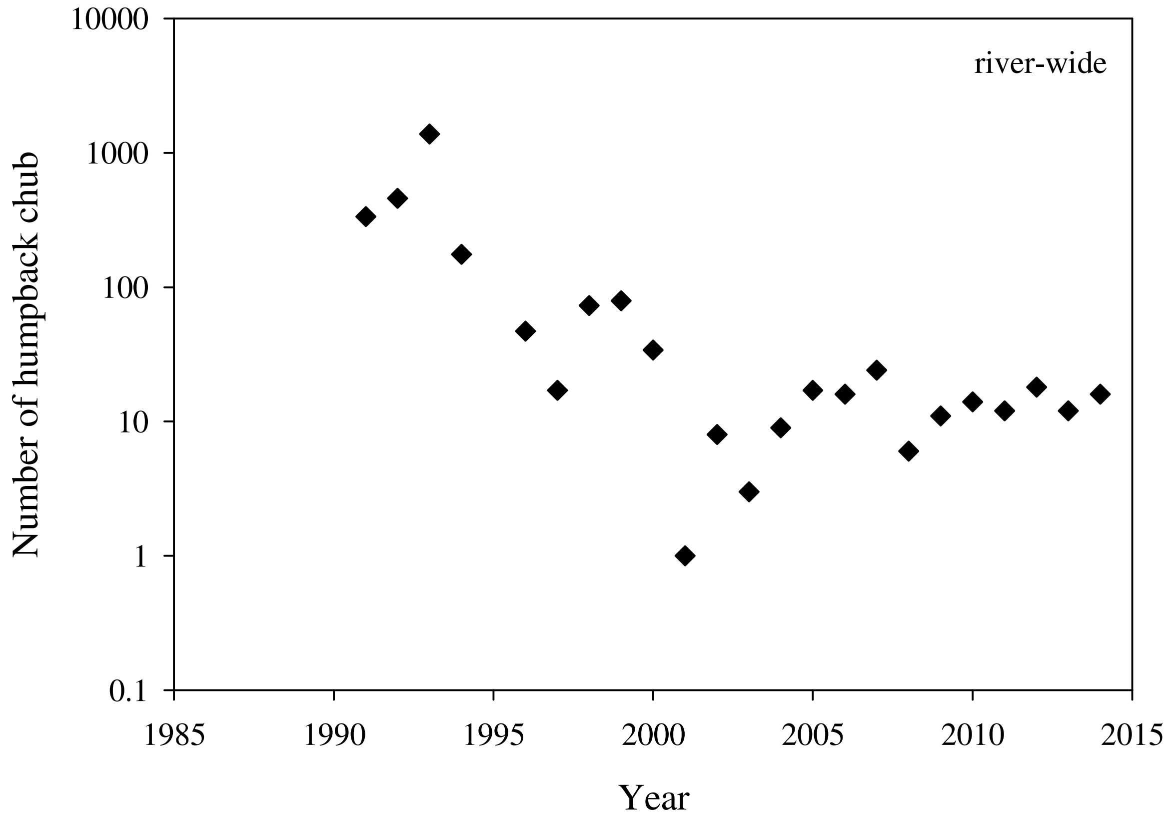

Figure 11. Number of humpback chub ($\log_{10}$ scale) captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 1991–2014, all reaches. Note: the number of sample sites differs from year to year.

Nonnative Fish

Rainbow Trout

River-wide mean CPUE for rainbow trout was 43.0 fish/hour in 2014 (Figure 3). There wasn't a significant trend in the river-wide mean CPUE over the past five years (Table 5). In 2014, rainbow trout CPUE mean significantly decreased downstream by reach (regression: $F_{1,5}$ =16.0, P = 0.0161; Figure 4). The mean CPUE for rainbow trout was highest in Reach 1, 155 fish/hour [132, 178], declining downstream with the lowest levels found in Reach 6, 0.33 fish/hour [0.000, 0.682], this is consistent with previous years (Figure 12). The length-frequency histogram from 2014 showed one main cohort centered at 300 mm TL (Figure 13).

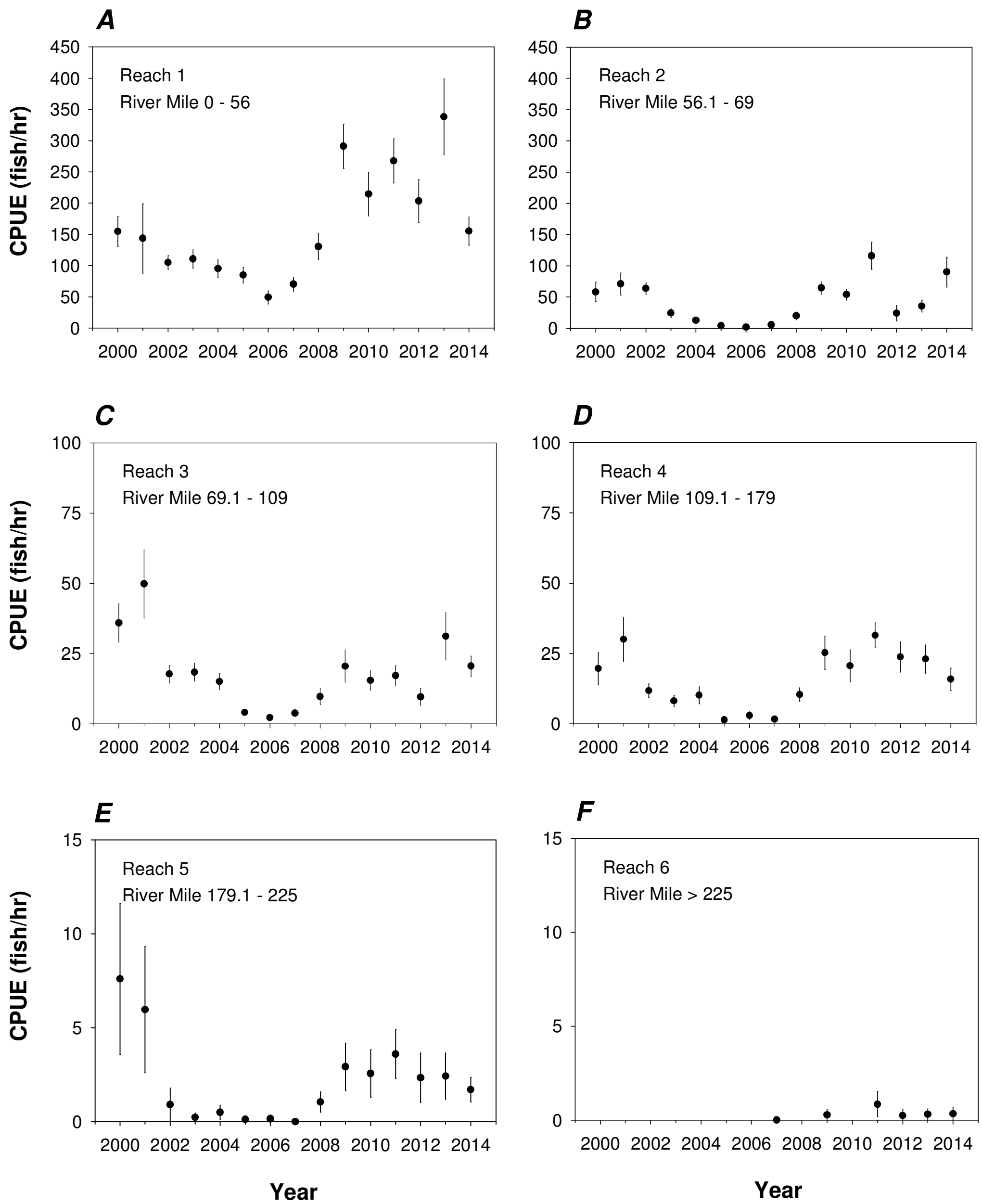

Figure 12. Mean CPUE (fish/hour) of rainbow trout captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014. Error bars represent 95% confidence intervals. Reach 6 was sampled in 2004-2007, and 2010, but data was not included because of high turbidity. Note: different Y axis scales between graphs; the number of sample sites differs from year to year.

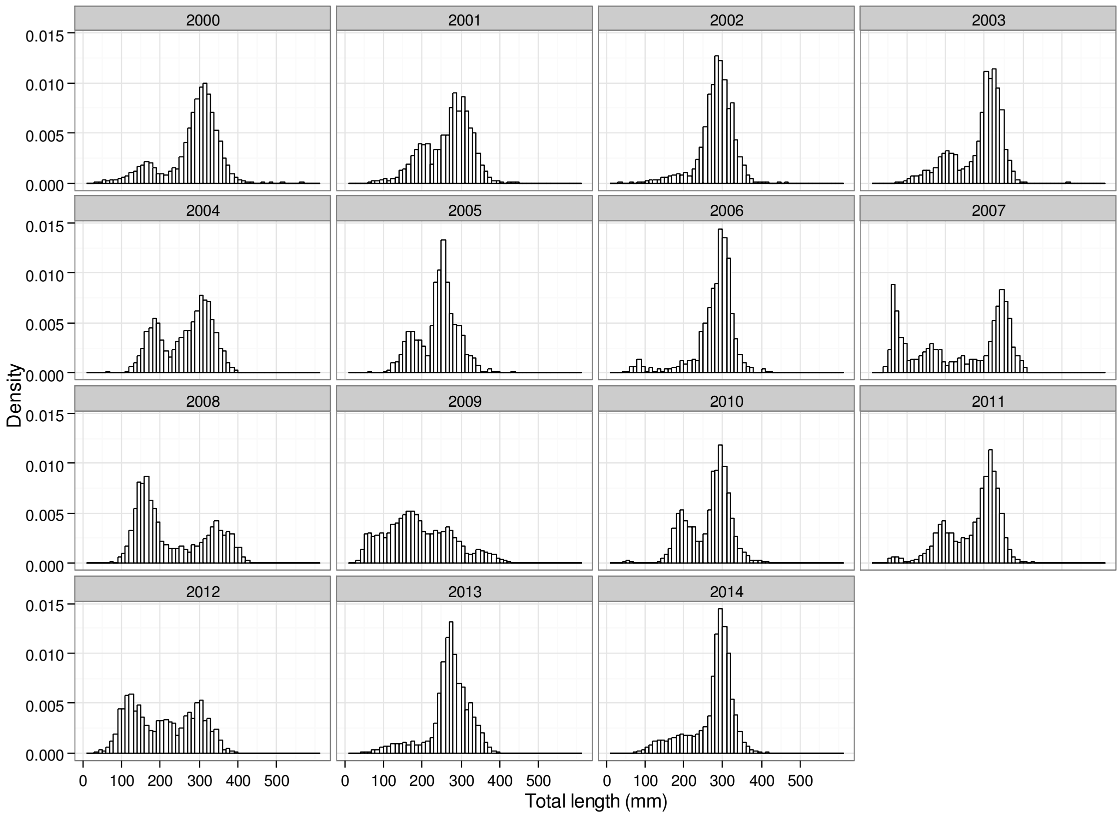

Figure 13. Length-frequency distribution of rainbow trout captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014, all reaches. Note: the number of samples sites differs from year to year.

Brown Trout

River-wide mean CPUE for brown trout was 1.5 fish/hour in 2014 (Figure 3). There was not a significant trend in the river-wide mean CPUE over the past five years (Table 5). In Reach 2 (contains the Little Colorado River at RM 61), there was a significant increase in brown trout mean CPUE since 2006 (R^2=0.679, $F_{1, 8}$ = 9.12, p = 0.0194; Figure 4). Mean CPUE is typically highest in reach 3, in close proximity to Bright Angel Creek (RM 90). Brown trout catch rates in 2014 for reach 3 were the lowest they have been since 2006 (Figure 14). The length-frequency histogram from 2014 showed a strong young of the year cohort, fish less than 100 mm (Figure 15).

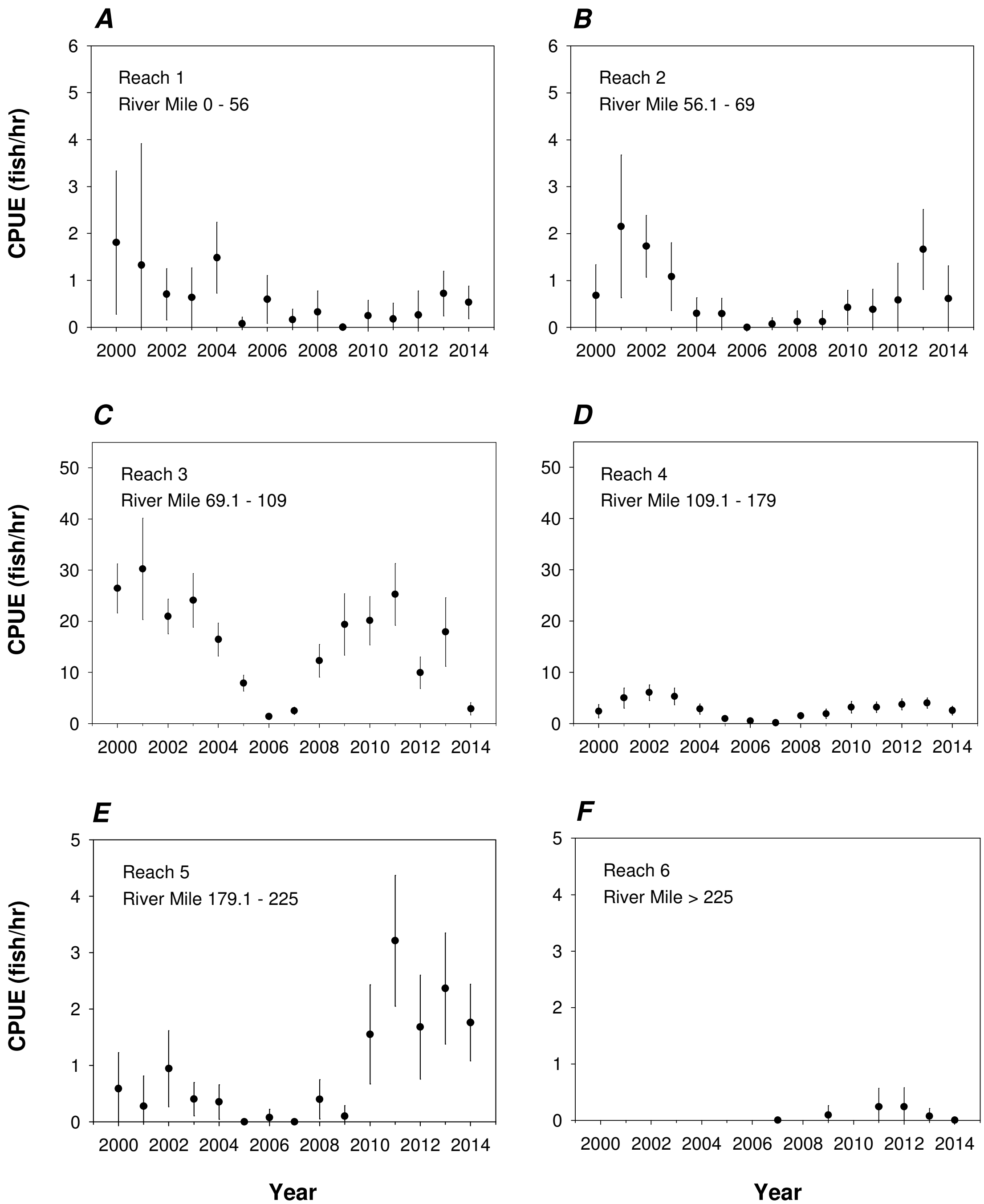

Figure 14. Mean CPUE (fish/hour) of brown trout captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014. Error bars represent 95% confidence intervals. Reach 6 was sampled in 2004-2006, and 2010, but data was not included because of high turbidity. Note: different Y axis scales between graphs; the number of sample sites differs from year to year.

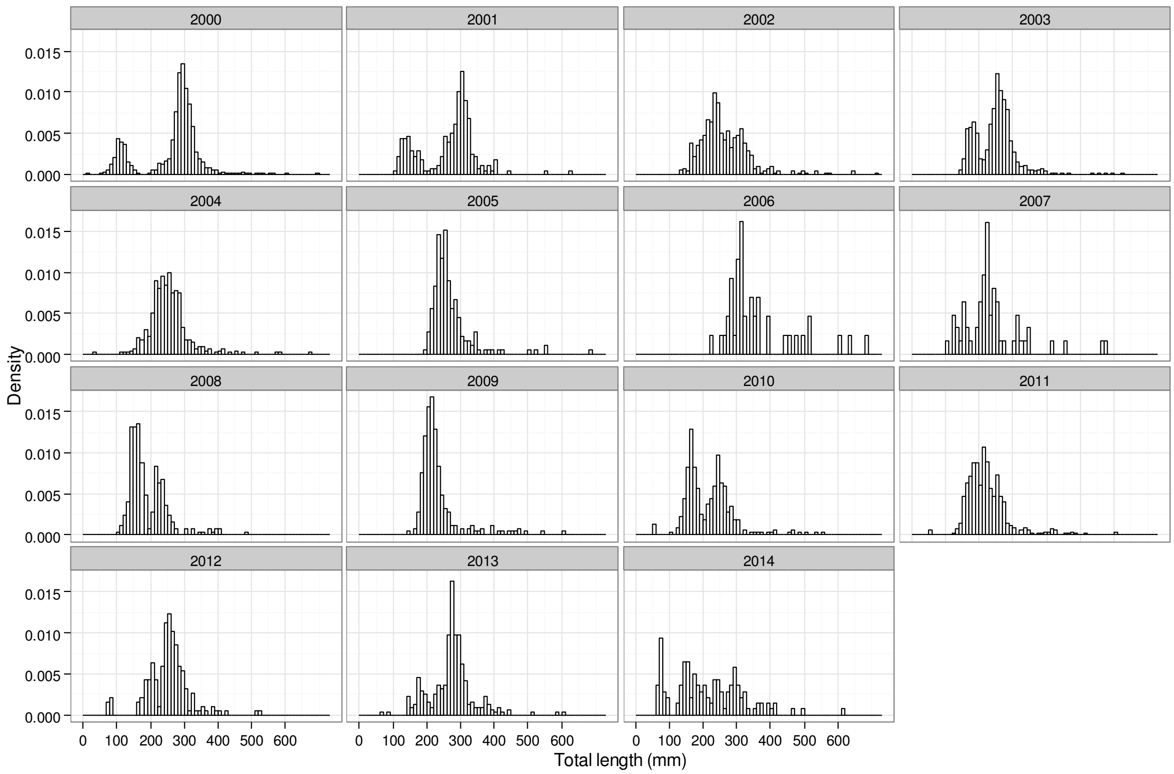

Figure 15. Length-frequency distribution of brown trout captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014, all reaches. Note: the number of sample sites differs from year to year.

Common Carp

River-wide mean CPUE for common carp was 1.9 fish/hour in 2014 (Figure 3). There was not a significant trend in the river-wide mean CPUE over the past five years (Table 5). Common carp catch rate is generally much lower upstream near Lees Ferry, and increases downstream as water temperatures warm (Figure 16). The length-frequency histogram from 2014 showed two distinct cohorts (Figure 17).

Other Nonnative Fish

Other nonnative fishes captured were black bullhead, channel catfish, fathead minnow, gizzard shad, mosquitofish, red shiner, and yellow bullhead (Table 3). None of these fishes were captured in adequate numbers to conduct summary statistics.

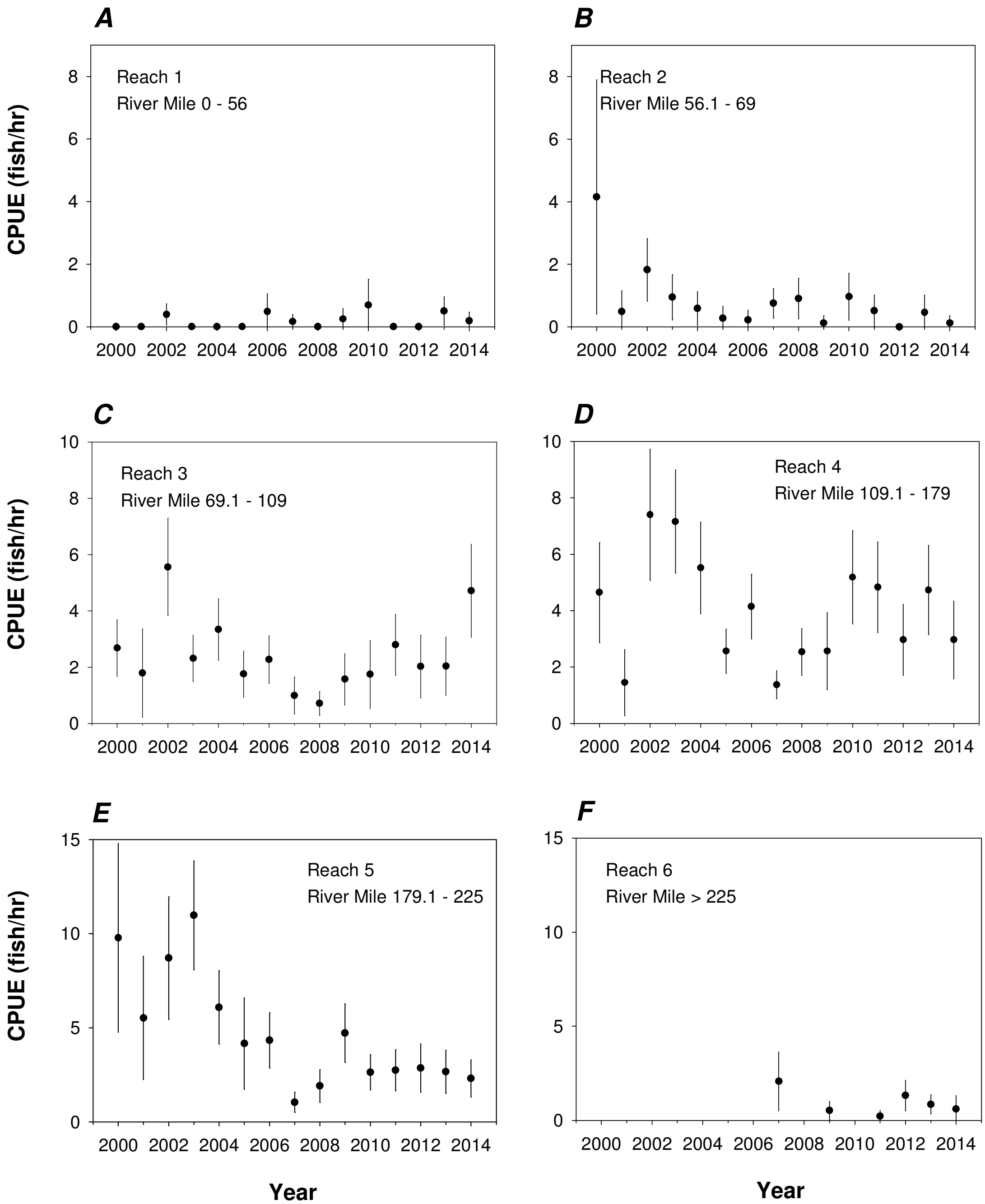

Figure 16. **Mean CPUE (fish/hour) of common carp captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014. Error bars represent 95% confidence intervals. Reach 6 was sampled in 2004-2006, and 2010, but data was not included because of high turbidity. Note: different Y axis scales between graphs; the number of sample sites differs from year to year.**

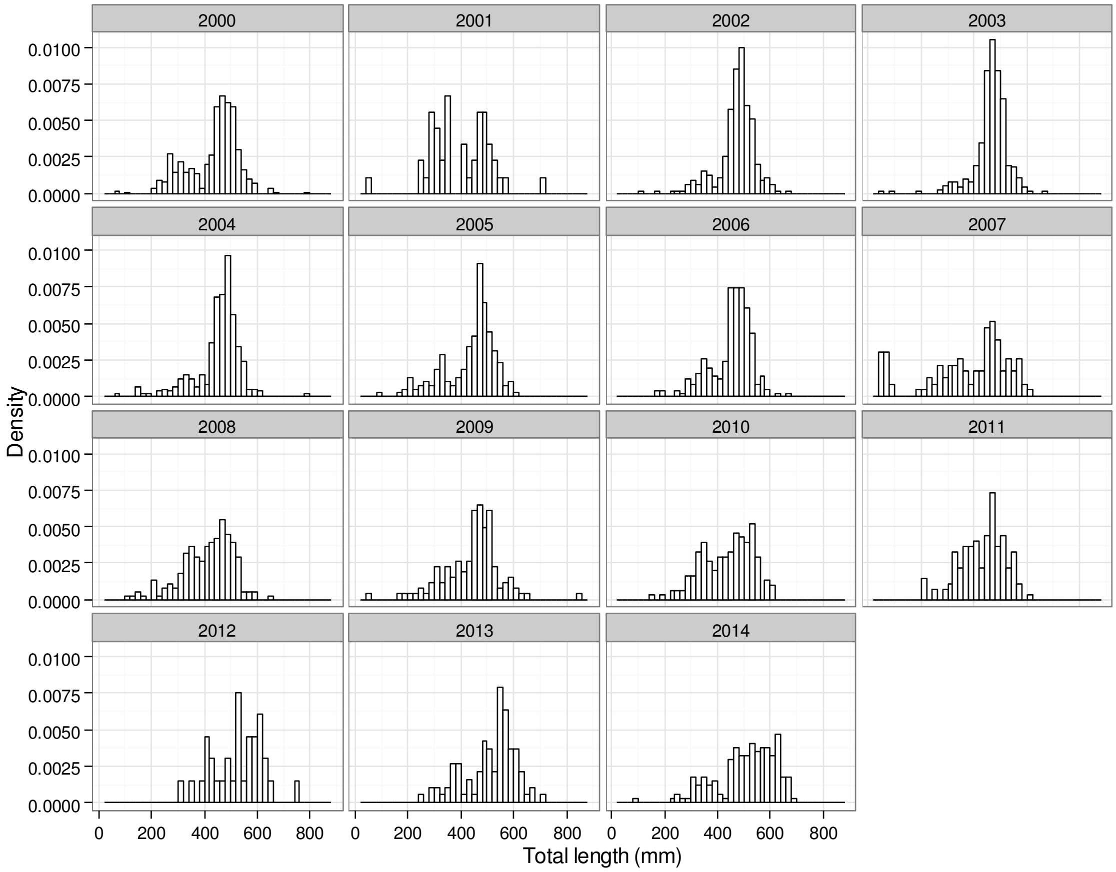

Figure 17. Length-frequency distribution of common carp captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2000–2014, all reaches. Note: the number of sample sites differs from year to year.

Little Colorado River Confluence Area

Mean CPUE of rainbow trout and brown trout varies above and below the vicinity of the Little Colorado River (Figure 18). Above the Little Colorado River confluence, mean CPUE for rainbow and brown trout was 132.3 fish/hour [106, 159] and 0.82 fish/hour [0.056, 1.58], respectively. In the 20 mi reach downstream of the confluence, mean CPUE was 24.9 fish/hour [15.2, 31.3] and 0.48 fish/hour [0.00, 1.28], respectively. Rainbow trout CPUE shows no significant trends in the two reaches immediately above or below the LCR over the last five years (2010-2014). Mean brown trout CPUE has shown a significant increasing trend for the area 20 miles above the LCR confluence over the past five years (regression: $F_{1,4}$ =13.1, P = 0.0364). Brown trout CPUE in the reach below the LCR did not show any significant trends.

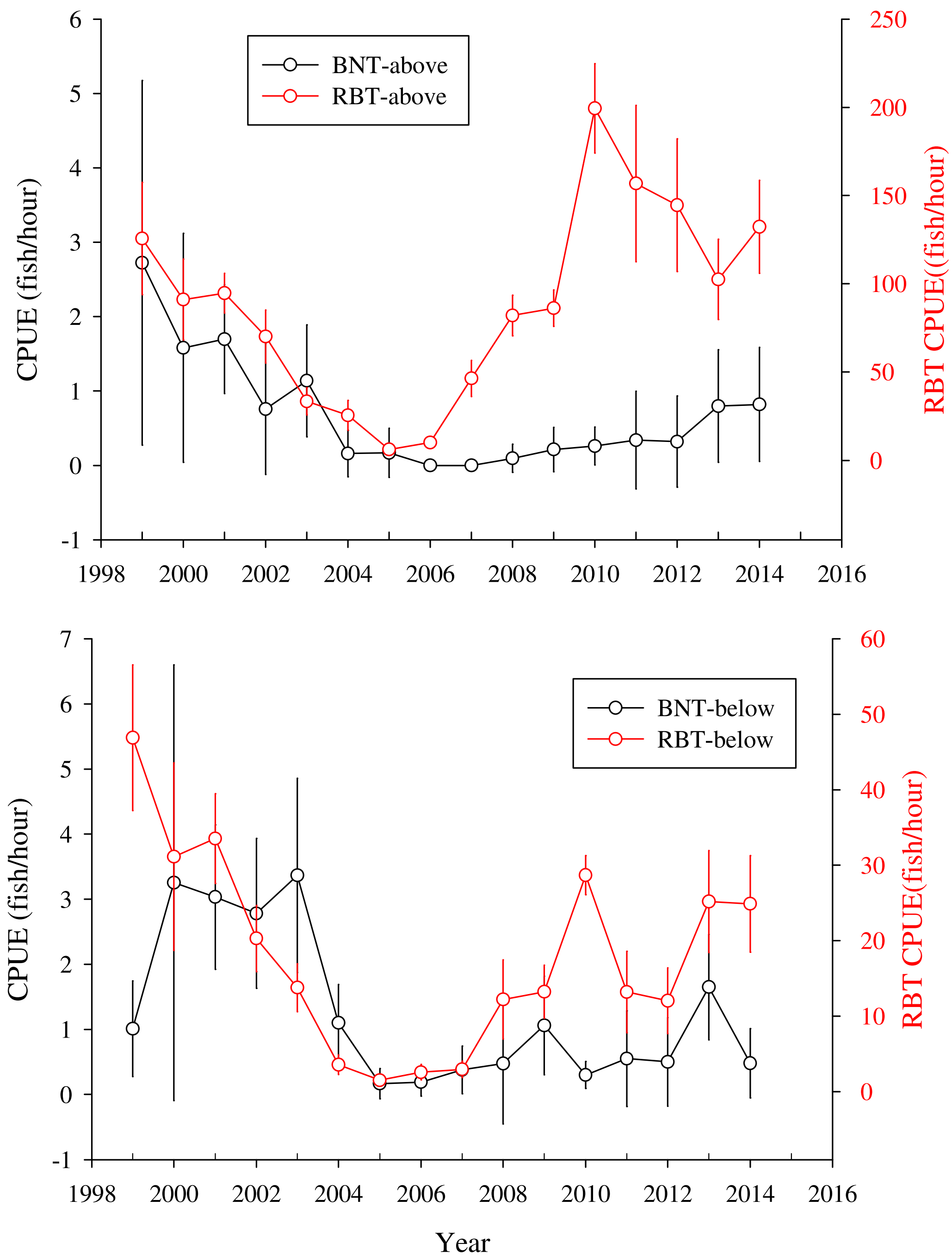

Figure 18. **Mean CPUE (fish/hour) of rainbow and brown trout captured within 20 mi. upstream (RM 41.5-61.5) and downstream(RM 61.5-81.5) of the Little Colorado River confluence area, during electrofishing surveys in the Colorado River, 2000–2014. Error bars represent 95% confidence intervals.**

Discussion

This year (2014) a new contract for boatmen was in place, consequently our boat electrofishing operators had limited to no experience with electrofishing. This inexperience may have affected our results for this year. A number of sites had to be thrown out due to mistakes in recording time spent electrofishing or other errors. When we compared CPUE among an experienced and unexperienced boatman, the experienced boatmen had twice the CPUE as the other. While we expect some difference among boatmen, we did not expect the amount of variance in CPUE explained by boatmen to be that high (as indicated by high F ratio). In comparisons (not published) of experienced boatmen electrofishing at Lees Ferry most of the explained variation in CPUE was due to flow and habitat, not the boatmen.

Turbidity during our fall trip (Diamond Creek downstream) was relatively high (433-573 NTUs) which can also affect electrofishing. While fish may have been stunned, due to high levels of turbidity netters may not have seen many fish. In addition to downstream data not analyzed from one trip in 2009 and 2010 (see methods), we decided to exclude data from 2004-2006 and 2010 for Reach 6, as unfortunately no turbidity readings were taken and turbidity was just recorded as “high”. We present 2014 results for Reach 6, which had high turbidity, because the actual turbidity values are known and presented. Interestingly, the USGS gage above the Diamond Creek inflow recorded much lower levels of turbidity (Table 2) than what we measured in the field. It is possible that the data downloaded from the USGS site for that gage was provisional and may change in the future.

Native Fish

There were no significant trends in river-wide CPUE within the last five years for flannelmouth sucker. The river-wide mean CPUEs for flannelmouth sucker have remained relatively consistent over the past five years ranging from 18.1 fish/hour [15.1, 21.1] to 19.9 fish/hour [17.01, 22.79] with the exception of 2011, 56.6 fish/hour [48.1, 65.2]. In May-August of 2011, equalization flows were established to help balance the water levels between Lake Powel and Lake Mead. These were steady flows that ranged from ~23,000-26,000 ft^3/s, which inundated vegetated shoreline habitats. We hypothesize that the newly inundated habitat could have influenced the magnitude of the increase in flannelmouth sucker catch rates due to habitat selectivity, and better access to these habitats with our electrofishing gear. In May-August of 2012 continuing into 2013, flows returned to normal operating conditions, fluctuating daily, peaking anywhere from ~12,000- 19,000 ft^3/s and dropping to 6,000-11,000 ft^3/s. As a result of this, 2012-2014 flannelmouth sucker mean CPUE was similar to pre-equalization years, 2009 and 2010. The large cohort of juvenile flannelmouth sucker captured in 2011 potentially shows that juvenile flannelmouth sucker preferred these newly inundated habitats and/or may be more vulnerable to electrofishing capture at higher flows.

The river-wide mean CPUEs for bluehead sucker in the last five years has declined. Starting in 2005 river-wide CPUE levels increased to a high in 2010, and have remained higher than levels recorded in 2000-2004. Reach 1 (RM 0-56) remains a poor location for bluehead sucker (CPUE ~ 0 fish/hour) most likely as a result of cold temperatures. Reaches 4-6 (RM 109.1- 270) within the past 6-10 years appear to have the highest relative abundance (CPUE of 2-4 fish/hour) of bluehead suckers. It should be noted that bluehead suckers are probably not adequately sampled by electrofishing within the Colorado River. Bluehead suckers are typically found in swift rocky habitat (McAda and Wydoski

1987), which is difficult and dangerous to sample via boat electrofishing, and having new boatmen that have little to no experience electrofishing may have contributed to low CPUE for this year (2014) compared to the past eight years.

We hypothesize that the significantly higher CPUE for speckled dace in 2011 was due to the equalization flows which caused these fish to become more vulnerable to capture via electrofishing for the same reasons as flannelmouth sucker. River-wide mean CPUE for speckled dace in 2013-2014 were more akin to levels observed from 2006-2008. Relative patterns of CPUE of speckled dace appear to mirror those of bluehead suckers with the exception of Reach 3, where mean CPUE is relatively lower.

Other Native Fish

In 2014, only 16 humpback chub were captured, which were not enough to conduct any analysis on the species. Previous research has shown humpback chub are not commonly vulnerable to electrofishing (Coggins 2008); thus, our mainstem electrofishing does not appear to be an effective monitoring technique for humpback chub at current densities. However, the number of humpback chub captured during AGFD mainstem electrofishing has decreased substantially since monitoring began in 1991. We captured a high of 1,379 humpback chub in 1993. We are not sure exactly why these numbers have changed so much it is something we will be investigating in the near future. Potentially sampling in the past was more directed around the LCR thus accounting for the higher numbers of humpback chub.

Nonnative Fish

There were no significant trends in river-wide CPUE within the last five years for rainbow trout, brown trout and common carp. The river-wide mean CPUEs for rainbow trout in 2014 was significantly less than the previous year. Some of this difference can probably be attributed to new boatmen. Most of the rainbow trout were captured within the first 60 river miles, when our new boatmen had the least amount of experience. As sampling progressed downstream their experience increased. We saw a similar result for brown trout CPUE, however, CPUE is highest within reach 3-5. Brown trout concentrations are highest in Reach 3 which includes Bright Angel Creek, a documented spawning location for brown trout (Maddux et al.1987, Valdez and Ryel 1995, Weiss et al. 1998). The National Park Service is currently (2013-2015) conducting brown trout removals in Bright Angel Creek and above and below its confluence to the Colorado River. If these efforts are effective we would expect to see a decline in brown trout CPUE in this reach, if the Bright Angel Creek is the main source of brown trout to the system. Due to sample stratification allocation we did not sample immediately around the confluence with Bright Angel Creek in 2014. Within Reach 3, it appears that brown trout CPUE is decreasing (past five years), however this was not a significant trend. Based on length frequency distributions from 2010-2014 it does appear that brown trout are reproducing and there is recruitment into the fishery. There are likely strong density-dependent effects, in particular for 2014 there is a relatively large cohort of fish below 100 mm.

The river-wide mean CPUEs for carp have remained similar since 2009, ranging from 1.63 fish/hour [1.22, 2.03] to 2.32 fish/hour [1.79, 2.86]. In 2014, carp were distributed throughout the river: lowest CPUE in Reach 2, 0.12 fish/hour [0, 0.40], and highest in Reach 4, 2.96 fish/hour [1.57, 4.34] With the exception of 2009, Reach 4 has had the highest mean CPUE for carp over the last five years; we hypothesize this is because of warmer Colorado River temperatures in conjunction with the presence of larger tributaries which may be used for spawning, (e.g. Havasu and Kanab Creek). Length frequency histograms reveal little to no recruitment as very few fish less than 200 mm are captured (2000-2014), with the exception of 2007. The increase in young of the year carp in 2007 may be a result of flooding in the Little Colorado River prior to the sampling trip leading to greater capture probability and not a result of increased recruitment in the main channel (Rogers et al. 2008). It is thought that little carp recruitment occurs in the mainstem Colorado and most occurs in the tributaries or in Lake Mead.

River-wide Interactions

It is important to interpret the river-wide interactions of the six most common species to understand interspecific relationships. Rainbow trout comprise 99% of the fish community in Reach 1 in 2014. This is most likely because of the cold water temperatures in this reach, and secondarily of its proximity to Lees Ferry where most of the rainbow trout spawning occurs (Korman et al. 2012). Four other species were captured in this reach (brown trout (11), flannelmouth sucker (13), carp (3) and one bluehead sucker). Fish native to the Colorado River are typically warm water species and their density and percent of the fish community increases downstream in relation to increasing water temperatures. Down river there is a substantial decline in rainbow trout mean CPUE in Reach 2 and throughout the rest of the river through Reach 6.

Nonnative fishes are known to negatively affect native fishes (Anderson 2010). These negative interactions could be through displacement, recruitment limitations, competition or predation (Coggins 2008,Yard et al. 2011). Some of the more common nonnative fishes that predate upon the native fishes are: rainbow trout, brown trout and channel catfish (*Ictalurus punctatus)* (Marsh and Douglas 1997, Yard et al. 2011). Differential resource use between young of year native fishes and smaller bodied nonnatives (e.g. fathead minnows (*Pimephales promelas*) and red shiners (*Cyprinella lutrensis*) may limit recruitment of native fish species due to competition, and potentially predator avoidance (Childs et al. 1998). Nonnative fishes with similar niches to native fishes (e.g. common carp and flannelmouth sucker), may cause habitat displacement (Coggins 2008).

A mechanical removal of nonnative fish species in the Little Colorado River Reach (RM 56.3-65.7) was implemented from 2003-2006 and one trip in 2009. This removal effort coincided with drought years that caused low water levels in Lake Powell. As a result, water releases from GCD were warmer than average. It is thought that the combination of removal of nonnatives and warmer water releases helped in recruitment of native fishes in this area (Coggins 2008, Coggins et al. 2011).

Little Colorado River Confluence Area

We analyzed rainbow and brown trout CPUE 20 miles upstream (RM 41.5- 61.5) and downstream (RM 61.5- 81.5) of the Little Colorado River (LCR) as this is an area of interest concerning the recruitment of the endangered humpback chub. Over the last five years rainbow trout CPUE shows no significant inclining or declining trend in this area, though there are notable differences in rainbow trout CPUE above and below the LCR; the CPUE above the LCR is significantly higher than the CPUE below the LCR. This is likely due to the increased sediment input by the LCR, which can limit natural recruitment via sedimentation of redds, increasing water temperatures (Hicks et al. 1991), and decreased ability to sight feed due to increased turbidity (Stuart-Smith et al. 2004).

Brown trout CPUE has shown a significant increasing trend for the area 20 miles above the LCR confluence over the past five years. This could be a compensatory response from mechanical removal efforts (Meyer et al. 2006, Coggins 2008, Coggins et al. 2011) from 2003-2006 and one trip in 2009. There appears to be a shift to a smaller size in length distribution. For 2006-2010 there was a significant increasing trend in brown trout CPUE below the LCR, after the last year of mechanical removal. Analysis of the past five years reveals no trend in CPUE below the LCR.

Conclusions

Rainbow trout continue to be prevalent in the upper reaches (Marble Canyon) and native fish continue to dominant the river below the Little Colorado River. Despite trout removal efforts around Bright Angel Creek over the past three years by the National Park Service, this area (Reach 3) maintains the highest CPUE for brown trout. Of note, bluehead sucker are infrequently captured, and are probably not adequately sampled by our electrofishing surveys.

Since the decline in water levels in Lake Mead, the Colorado River now extends about 15 river miles downstream of Pearce Ferry. There has been greater interest in the fish community in this area from stakeholders as a result of recent findings of endangered razorback sucker utilizing this area. This reach below Diamond Creek has not been routinely nor adequately sampled in the past, so in the future we will reduce our sampling efforts in Marble Canyon and shift that effort to the area below Diamond Creek to Pearce Ferry. We will sample the reach below Diamond Creek in both the spring/summer as well as the fall.

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Appendix A. Trip information from 2000–2013, including flow (cubic feet per second) at Lees Ferry and temperature (°C) at river mile 87. An asterisk (*) indicates that only data from upstream of the Little Colorado River confluence was analyzed due to high turbidity downstream during the trip.

Trip	Trip ID	Start date	End date	No. of days	Start river mile	End river mile	Distance sampled (mi)	Lees Ferry flow (mean ± SD)	River mile 87 temperature (mean ± SD)
1	GC20000604	6/4/2000	6/17/2000	13	20.7	221.7	201.1	8,230 ± 59	14.8 ± 0.2
2	GC20000721	7/21/2000	8/3/2000	13	36.2	218.7	182.5	8,378 ± 51	15.2 ± 0.1
3	GC20000825	8/25/2000	9/5/2000	11	18.4	94.7	76.3	10,038 ± 5,660	14.1 ± 0.3
4	GC20010309	3/9/2001	3/18/2001	9	39.3	196.7	157.4	10,444 ± 1,561	9.8 ± 0.2
5	GC20020214	2/14/2002	3/3/2002	17	12.0	218.4	206.4	10,304 ± 1,706	8.6 ± 0.3
6	GC20020404	4/4/2002	4/20/2002	16	14.6	216.5	201.9	10,305 ± 1,414	11.2 ± 0.3
7	GC20030405	4/5/2003	4/21/2003	16	8.7	224.1	215.4	10,013 ± 2,219	10.8 ± 0.7
8	GC20030503	5/3/2003	5/20/2003	17	12.4	218.5	206.1	10,722 ± 2,275	12 .0 ± 0.6
9	GC20040402	4/2/2004	4/19/2004	17	18.2	224.1	205.9	10,864 ± 1,879	11.2 ± 0.4
10	GC20040501	5/1/2004	5/17/2004	16	1.6	223.4	221.8	9,843 ± 1,905	12.7 ± 0.5
11	GC20041005	10/5/2004	10/11/2004	7	228.7	274.9	46.2	8,026 ± 1,518	15.6 ± 0.3
12	GC20050416	4/16/2005	5/3/2005	17	20.8	225.0	204.2	7,760 ± 1,697	12.3 ± 0.3
13	GC20050514	5/14/2005	5/30/2005	16	4.5	223.0	218.5	9,588 ± 2,015	13.7 ± 0.5
14	GC20050531	5/31/2005	6/5/2005	6	228.0	262.0	34.0	12,242 ± 3,216	14.1 ± 0.6
15	GC20060408	4/8/2006	4/25/2006	17	2.3	222.4	220.1	10,400 ± 1,631	11.5 ± 0.3
16	GC20060506	5/6/2006	5/22/2006	16	11.7	224.5	212.8	9,996 ±1,682	13.3 ± 0.6
17	GC20060523	5/23/2006	5/28/2006	6	226.5	274.6	48.0	9,871 ± 1,838	13.4 ± 0.4
18	GC20070308	3/8/2007	3/27/2007	19	8.6	223.2	214.6	9,819 ± 1,382	10.7 ± 0.3
19	GC20070915	9/15/2007	10/3/2007	18	8.8	265.0	256.2	10,321 ± 1,957	13.4 ± 0.5
20	GC20080205	2/5/2008	2/24/2008	19	17.7	224.4	206.7	10,606 ± 1,400	8.4 ± 0.4
21	GC20080327	3/27/2008	4/16/2008	20	17.4	224.7	207.3	10,331 ± 1,803	10.6 ± 0.4
22	GC20090228*	2/28/2009	3/17/2009	17	17.5	222.6	205.1	10,318 ± 1,547	9.8 ± 0.4
23	GC20090326	3/25/2009	4/16/2009	22	21.5	264.8	243.3	10,315 ± 1,839	10.3 ± 0.6
24	GC20100401*	4/1/2010	4/21/2010	20	27.1	261.6	234.5	10,364 ± 387	10.8 ± 0.7

Trip	Trip ID	Start date	End date	No. of days	Start river mile	End river mile	Distance sampled (mi)	Lees Ferry flow (mean ± SD)	River mile 87 temperature (mean ± SD)
25	GC20100506	5/6/2010	5/23/2010	17	12.2	222.5	210.3	10,013 ± 340	11.6 ± 0.6
26	GC20110507	5/7/2011	5/31/2011	25	1.8	261.1	259.3	20,756 ± 3,503	10.9 ± 0.6
27	GC20120511	5/11/2012	6/2/2012	22	3.9	222.5	218.6	9,912 ± 2,143	13.3 ± 0.3
28	GC20121001	10/5/2012	10/9/2012	4	239.8	259.7	19.9	8,016 ± 58	12.7 ± 0.3
29	GC20130404	4/4/2013	4/15/2013	11	12.4	225.4	213.0	9,199 ± 1,566	10.8 ± 0.6
30	GC20130525	5/25/2013	6/7/2013	13	8.9	214.5	216.5	10,819 ± 3,407	12.7 ± 0.5
31	GC20131028	10/28/2013	10/31/2013	4	226.5	266.1	39.6	7,747 ± 1,271	12.1 ± 0.5
32	GC20140403	4/3/2014	4/16/2014	13	1.49	215.39	213.9	8,625 ± 1,360	11.2 ± 0.7
33	GC20140524	5/24/2014	6/6/2014	13	14.68	225.30	210.62	8,880 ± 2,215	14.0 ± 0.7
34	GC20141020	10/20/2014	10/24/2014	4	236.03	270.10	34.07	10,207 ± 1,846	15.2 ± 0.2

Appendix B. Recapture information for Passive Integrated Transponder (PIT) tagged fish captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2014. [minus (-), upstream movement; plus (+), downstream movement] Fish marked in the Little Colorado River (LCR) were assigned the confluence river mile 61.75.

Species	Tag number	Date marked	River mile marked	Date recaptured	River mile recaptured	Days at liberty	Mark length (mm)	Recapture length (mm)	Distance moved (mi)	Absolute growth (mm/day)
BNT	3D9.1C2D14CB45	4/7/2009	154.92	4/13/2014	136.77	1832	323	495	-18.15	0.09389
BNT	3DD.003BA050DE	6/1/2013	88.48	4/9/2014	88.48	312	275	289	0	0.04486
BNT	3DD.003BA053E3	4/11/2013	114.18	4/12/2014	108.02	365	278	295	-6.16	0.04785
CRP	3D9.1BF198D2E2	5/13/2003	123.4	4/12/2014	108.02	3986	427	540	-15.38	0.02835
CRP	3DD.003BA04FC7	4/5/2013	29.97	4/5/2014	32.29	365	662	630	2.32	-0.08695
CRP	3D9.1BF1A0D977	4/19/2003	195.4	6/3/2014	194.39	4062	408	465	-1.01	0.01403
CRP	3DD.003BA05C1B	6/5/2013	171.31	6/1/2014	176.01	361	325	319	4.7	-0.01662
FMS	384.1B796BC13B	5/22/2011	157.98	4/10/2014	103.98	1054	340	440	-54	0.09487
FMS	384.36F2B294A8	9/19/2012	158.13	4/13/2014	137.04	571	326	386	-21.09	0.10503
FMS	3D9.1BF210E125	4/15/2007	LCR	4/6/2014	48.41	2549	373	481	-13.34	0.04238
FMS	3D9.1BF22A777C	8/9/2005	59.2	4/6/2014	49.36	3162	197	491	-9.84	0.09298
FMS	3D9.1BF252EB9A	8/15/2006	60	4/7/2014	57.02	2792	470	489	-2.98	0.00681
FMS	3D9.1C2D3C3D00	9/24/2010	158.55	4/14/2014	145.11	1298	321	354	-13.44	0.02542
FMS	3D9.1C2D8DAE52	9/14/2010	60.55	4/7/2014	59.19	1301	390	480	-1.36	0.06917
FMS	3DD.003BA0271E	7/31/2013	157.14	4/10/2014	103.01	253	380	388	-54.13	0.03159
FMS	3DD.003BA03461	7/31/2013	157.7	4/10/2014	103.55	253	360	369	-54.15	0.03553
FMS	3DD.003BA09948	11/21/2013	*	4/9/2014	85.51	139	292	305	N/A	0.09355
FMS	384.1B796A484A	5/26/2011	206.53	6/2/2014	190.29	1103	209	415	-16.24	0.18678
FMS	384.1B796A4BF2	5/27/2011	207.35	6/4/2014	216.47	1105	237	402	9.12	0.14933
FMS	384.36F2B24810	4/22/2013	LCR	5/28/2014	50.64	401	485	500	-11.11	0.03743
FMS	384.36F2B2A10E	9/21/2012	214.17	6/4/2014	214.22	621	259	332	0.05	0.11752
FMS	3D9.1BF24E087C	3/13/2006	62.3	5/27/2014	50.5	2997	477	553	-11.8	0.02536
FMS	3D9.1BF24E8C72	5/16/2006	116.9	5/27/2014	49.36	2933	303	535	-67.54	0.07910
FMS	3D9.1BF255FBF4	4/11/2008	174.6	5/31/2014	174.28	2241	296	462	-0.32	0.07407
FMS	3D9.1BF256241A	3/24/2007	195.7	5/30/2014	132.03	2624	313	483	-63.67	0.06478
FMS	3D9.1C2D2132D1	3/10/2009	120.22	5/31/2014	172.47	1908	432	472	52.25	0.02096

Species	Tag number	Date marked	River mile marked	Date recaptured	River mile recaptured	Days at liberty	Mark length (mm)	Recapture length (mm)	Distance moved (mi)	Absolute growth (mm/day)
FMS	3D9.1C2D3C3E92	4/15/2010	188.69	6/2/2014	189.9	1509	410	450	1.21	0.02651
FMS	3DD.003B9C2A4A	9/18/2013	158	5/29/2014	126.61	253	328	335	-31.39	0.02761
FMS	3DD.003BA01092	6/7/2013	191.01	6/3/2014	194.01	361	306	338	3	0.08863
FMS	3DD.003BA036CC	6/6/2013	191.65	6/2/2014	191.65	361	221	279	0	0.16070
FMS	3DD.003BA03CAD	6/7/2013	213.76	6/4/2014	215.19	362	377	407	1.43	0.08289
FMS	3DD.003BA04FC1	4/14/2013	195.42	5/31/2014	173.35	412	386	383	-22.07	-0.00728
FMS	3DD.003BA0559C	4/15/2013	225.01	6/5/2014	224.7	416	208	294	-0.31	0.20674
FMS	3DD.003BA055A4	4/15/2013	224.72	6/6/2014	225.01	416	362	443	0.29	0.19463
FMS	3DD.003BA055B9	4/15/2013	225.3	6/6/2014	225.16	416	217	318	-0.14	0.24271
FMS	3DD.003BA05864	4/15/2013	225.13	6/5/2014	225.13	416	215	328	0	0.27164
FMS	3DD.003BA05866	4/15/2013	224.86	6/5/2014	225.13	416	274	345	0.27	0.17066
FMS	3DD.003BA0586E	4/15/2013	224.56	6/5/2014	224.56	416	252	322	0	0.16826
FMS	3DD.003BA05A94	4/14/2013	195.54	6/4/2014	208.55	415	322	369	13.01	0.11322
FMS	3DD.003BA05A99	4/14/2013	195.67	6/2/2014	191.41	414	311	374	-4.26	0.15218
FMS	3DD.003BC8A2D4	4/15/2014	211.1	6/2/2014	178.24	47	402	401	-32.86	-0.02120
RBT	384.36F2B25008	5/17/2012	86.99	4/9/2014	86.87	692	217	341	-0.12	0.17926

* River mile not entered in database.

Appendix C. Recapture information for Floy tagged fish captured during electrofishing surveys on the Colorado River between Lees Ferry and Lake Mead, 2014. [minus (-), upstream movement; plus (+), downstream movement] One Floy tagged fish that was recaptured did not have a mark event in the database.

Species	Tag number	Date marked	River mile marked	Date recaptured	River mile recaptured	Days at liberty	Mark length (mm)	Recapture length (mm)	Distance moved (mi)	Absolute growth (mm/day)
CRP	USGS 08508	4/19/2006	132.9	4/13/2014	137.87	2915	486	492	4.97	0.00206
RBT	USGS 21448	5/11/2011	57.91	4/7/2014	57.82	1062	226	321	-0.09	0.08946
RBT	USGS 15178	9/13/2010	59.94	4/7/2014	59.36	1301	278	342	-0.58	0.04919
RBT	USGS 21361	5/11/2011	58.44	4/7/2014	58.51	1062	235	371	0.07	0.12807